NOTICE

All drawings located at the end of the document.

Draft

TECHNICAL MEMORANDUM NO. 2

HUMAN HEALTH RISK ASSESSMENT FOR OPERABLE UNIT NO. 3 ROCKY FLATS PLANT

EXPOSURE SCENARIOS

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL RESTORATION PROGRAM

April 23, 1993

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BY G. T. Ostdiek 820
DATE 6-4-93

TITLE: Table of Contents

Approved By:

Name (Date) / /

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LIST OF ACRONYMS AND ABBREVIATIONS

The following is a list of acronyms and abbreviations used throughout this report.

AEC	United States Atomic Energy Commission
BRA	Baseline Risk Assessment
CDH	Colorado Department of Health
CDOW	Colorado Department of Wildlife
cm/yr	centimeters per year
CSM	conceptual site model
COPC	chemicals of potential concern
DCF	dose conversion factor
DOE	Department of Energy
DCG	(DOE) Derived Concentration Guide
DRCOG	Denver Regional Council of Governments
EG&G	EG&G Rocky Flats, Inc.
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
FRICO	Farmers Reservoir and Irrigation Company
ft	foot
ft/day	feet per day
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
IAG	Interagency Agreement
IHSS	Individual Hazardous Substance Sites
JEFFCO	Jefferson County, Colorado
km	kilometer
m	meter
m/day	meters per day
MRI	Midwest Research Institute
m/s	meters per second
OU 3	Operable Unit No. 3
PHE	Public Health Evaluation
RFI/RI	RCRA Feasibility Investigation/Remedial Investigation
RFP	Rocky Flats Plant
RME	reasonable maximum exposure
TM	technical memorandum
UDFCD	Urban Drainage and Flood Control District (Denver, Colorado)
USGS	United States Geological Survey

Section 1
PURPOSE AND SCOPE

1.0 PURPOSE AND SCOPE

1.1 PURPOSE

The purpose of this Exposure Scenarios Technical Memorandum (TM) is to present the exposure scenarios for the Human Health Risk Assessment (HHRA). This TM supports the HHRA for the Operable Unit No. 3 (OU 3) located adjacent to the Rocky Flats Plant (RFP). OU 3 consists of the following Individual Hazardous Substances Sites (IHSSs):

- Contamination of Soils (IHSS 199)
- Great Western Reservoir (IHSS 200)
- Standley Lake (IHSS 201)
- Mower Reservoir (IHSS 202)

The HHRA will evaluate potential human health risks under current and future land uses using the scenarios described in this TM. The exposure assessment portion of the HHRA is used to estimate the potential magnitude, frequency, duration, and route of exposure for these receptors. In accordance with the Interagency Agreement (IAG, 1991), Attachment 2, Section VII.D, this TM describes "the present, future, potential, and reasonable use exposure scenarios, with a description of the assumptions made and use of data." During the exposure assessment phase of the HHRA, these factors will be used to estimate intakes of chemicals of potential concern (COPC) by the hypothetical receptors described by the exposure scenarios.

1.2 SCOPE

The scope of the TM is limited to the identification of current and potential future land use scenarios and complete exposure pathways by which COPCs may be transported to human receptors.

Scenarios that will be modelled to determine potential radiological and chemical intakes through contact with media and related exposures are presented according to the U.S. Environmental Protection Agency (EPA) concept of reasonable maximum exposure (RME). The RME can be defined as conservative, and provides an upper parameter on the realistic range of exposures that may occur at the site should all exposure assumptions be realized simultaneously (EPA, 1990b). EPA uses the term "potential" to mean "a reasonable chance of occurrence within the context of the RME scenario" (EPA, 1990a).

1.3 REPORT OVERVIEW

This report is divided into five sections, with information from each section used to develop the following section. These sections are:

- Section 2.0, Physical Setting
- Section 3.0, Land Use in the OU 3 Study Area
- Section 4.0, Exposure Scenarios
- Section 5.0, Exposure Models
- Section 6.0, References

Section 2.0, Physical Setting, presents the physical setting of OU 3. Information in Section 2.0 includes a description of the four IHSSs that comprise OU 3, physical setting, climate, geology, surface water, and groundwater.

Section 3.0, Land Use In the OU 3 Study Area, identifies the current and potential future land uses within the OU 3 study area, based on data available from the appropriate local planning authorities. Exposure assessment requires a review of existing and future land and resource uses to develop exposure scenarios reflecting the activity and land use patterns that may lead to current or potential future exposures. In addition, potential future land uses outside of the OU 3 study area are briefly discussed in terms of whether such land uses could affect the OU 3 study area.

Section 4.0, Exposure Scenarios, presents conceptual site models and exposure scenarios developed for current and future projected land use. Exposures can only be assessed for pathways through which people (receptors) may contact COPCs. Section 4.0 identifies applicable pathways and shows how each pathway fits the developed exposure scenario.

The exposure scenarios are based on the physical setting described in Section 2.0, the land uses described in Section 3.0, and from the conceptual site models and potential human receptors presented in Section 4.0.

Section 5.0, Exposure Models, summarizes the approach that will be used to quantify intake. The magnitude of potential exposure will be assessed by estimating the frequency and duration of the receptor's expected contact with environmental media. This section utilizes the exposure scenarios and pathways presented in Section 4.0 and implements media intake factors that will be used to quantify the magnitude of potential exposures.

Section 2
PHYSICAL SETTING

2.0 PHYSICAL SETTING

This section provides general information on the RFP and the surrounding region. Subsections 2.1 and 2.2 provide background information on the location and history of the RFP and a description of RFP and OU 3, respectively. Subsection 2.3 describes the physical environment of the RFP and OU 3 area including the physical setting, climate, geology, surface water, and groundwater.

2.1 LOCATION AND HISTORY OF ROCKY FLATS PLANT

The RFP is located approximately 16 miles (26 km) northwest of Denver and approximately 10 miles (16 km) south of Boulder (Figure 2-1). The site is located on a high, arid plain at about 6,000 feet (1,800 m) above sea level and covers 6,550 acres (2,620 hectares) in northern Jefferson County, Colorado. The RFP is part of a nationwide nuclear weapons complex owned by the Department of Energy (DOE). The facility is currently contractor-operated by EG&G Rocky Flats, Inc. (EG&G) as a nuclear weapons research, development, and production complex. The RFP fabricated components for nuclear weapons from plutonium, uranium, beryllium, and stainless steel. Support activities have included chemical recovery and purification of recyclable transuranic radionuclides, and research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics (DOE, 1988). Several of these activities are ongoing.

Main production facilities are located near the center of the RFP within a fenced security area of 384 acres. The remaining plant area contains limited support facilities and serves as a buffer zone to major production areas. Construction of the RFP began in 1951, and the first production activities commenced the following year. Operation of the RFP fell under the administration of the U.S. Atomic Energy Commission (AEC) from 1951 until the AEC was dissolved in January 1975. Responsibility for the plant was then transferred to the Energy Research and Development

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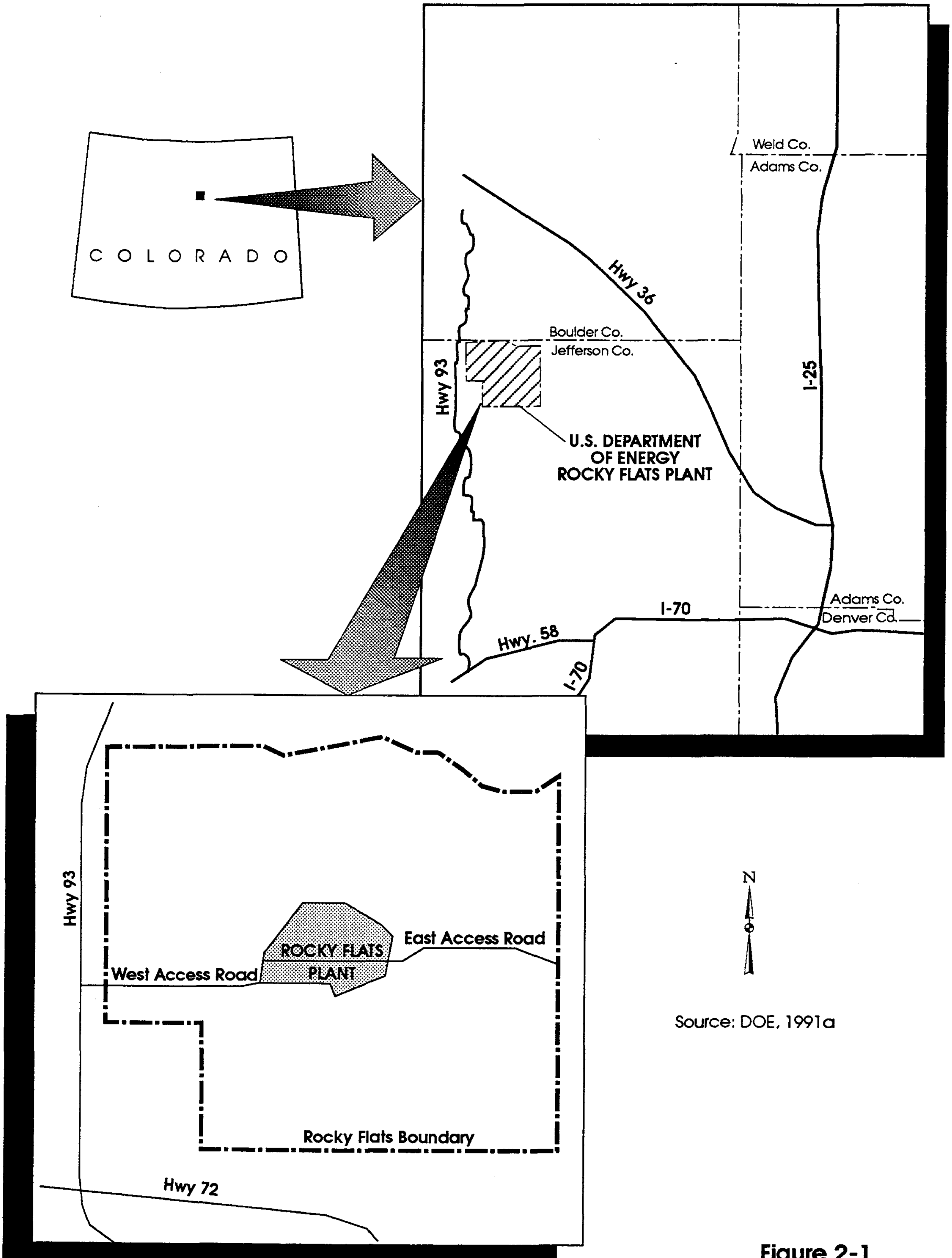

Source: DOE, 1991a

Figure 2-1
LOCATION OF
ROCKY FLATS PLANT

Administration (ERDA), which was succeeded in 1977 by DOE. Dow Chemical USA was the prime operating contractor of the facility from 1951 until 1975. Rockwell International succeeded Dow Chemical USA from 1975 through 1989, when EG&G assumed RFP operations.

2.2 DESCRIPTION OF OU 3

The IAG signed by the DOE, EPA, and the Colorado Department of Health (CDH) groups the 178 IHSSs at the RFP into 16 OUs. Areas are organized into OUs based upon one or more common features such as the type of contaminant, the environmental media, the technologies likely to be used for remediation of the area, or the previous use of the contaminated area (IAG, 1991).

OU 3 is unique among RFP OUs in that it is located outside the RFP boundaries (Figure 2-2). The four IHSSs (199 to 202) included in the OU 3 study area probably represent a gradient of contamination from the RFP and are therefore "receiving bodies" and not sources of contamination (i.e., "Sources" in the sense of containing facilities/burials or other sources of contaminants). The RFP is no longer a "Source" of contamination and consequently, the OU 3 study area is not expected to receive added contaminant loading or any episodic pollution releases. Current operations at the RFP meet all state and federal standards (EG&G, 1990b).

Figure 2-2 shows the boundaries of the OU 3 study area as defined using historical data and recent sampling events (see Subsections 2.1.4.2 and 6.3.2.2 of the RFI/RI Final Work Plan for OU 3 [DOE, 1992c]). Additional data may lead to a redefinition of the study area. However, the current study area, as defined in Figure 2-2, is believed to be sufficient for the purpose of estimating upper-bound potential exposures and subsequent risks because the study area encompasses those properties adjacent to the RFP and therefore the areas most likely to be affected by RFP activities.

2.2.1 IHSS 199–Soils

IHSS 199 is composed of soils outside of the RFP boundary that are contaminated by historical releases from RFP, including 350 acres of remedy acreage located just east of Indiana Street (Figure 2-2). The extent of offsite soil contamination, resulting from historical RFP releases, have not been conclusively defined. This TM discusses IHSS 199 within the OU 3 study area. It is not anticipated that IHSS 199 extends beyond the OU 3 study area. However, as previously stated, the OU 3 study area may be redefined as a result of the RFI/RI.

A portion of the IHSS 199 known as the remedy acreage (Figure 2-2) was prescribed as a result of a 1975 lawsuit filed against Rockwell International Corporation, Dow Chemical Company, and the United States of America by the Church (McKay) plaintiffs and the Great Western Venture Partnership. The plaintiffs claimed that their land had been damaged by radioactive contaminants from RFP. In December 1984, the plaintiffs and defendants reached a remedy settlement (Agreement No. 87-02.02, 1987) that called for ripping, plowing, and tilling affected soils to reduce plutonium concentrations. The Agreement also stipulated the transfer of about 250 acres of land to Jefferson County and about 100 acres to the City of Broomfield. These lands are currently not open to the public (EG&G, 1991b). Approximately 120 acres of Jefferson County land has been addressed to date. At this time, Broomfield has not requested that the RFP begin remediation on its affected acreage, but has excluded access of this acreage to the public (DOE, 1992c).

2.2.2 IHSS 200–Great Western Reservoir

IHSS 200 consists of Great Western Reservoir, the associated drainages leading into and out of the reservoir, and their respective sediments. For the purpose of the HHRA, the sediments in this IHSS are defined as unconsolidated deposits of particulates that originated from the weathering of rocks and organic matter and were transported by water and deposited in drainages.

Great Western Reservoir is located 1.5 miles east of the RFP's eastern boundary (Figure 2-2). Originally, the reservoir was 42 feet deep and had a storage capacity of 1,420 acre-feet. In 1955, the Turnpike Land Company purchased the reservoir and established the Broomfield Heights Mutual Service Association, which owned and operated water and sewer utilities for the Broomfield Heights development. In 1958, the reservoir was enlarged to its current storage capacity of 3,250 acre-feet (1.06 billion gallons) and is now 62 feet deep (Schoner, 1991). In 1962, the City of Broomfield bought the water and sewer services from the Turnpike Land Company and in 1971 fenced the area around Great Western Reservoir to prevent public access (CDH, 1992b).

The reservoir previously received surface water runoff from Clear Creek through Lower Church Ditch; from Coal Creek through McKay Ditch; and directly from Upper Church Ditch. Prior to construction of a diversion ditch in 1989, water from Walnut Creek's north and south branches flowed from RFP directly into Great Western Reservoir. Flows from Walnut Creek are now treated at the RFP and are diverted south around Great Western Reservoir into the drainage ditch below the reservoir's outlet (Figure 2-2). This diversion, called the Broomfield Diversion Ditch, prevents treated surface water from RFP from reaching Great Western Reservoir (EG&G, 1991b).

Since 1955, Great Western Reservoir has been the primary drinking water source for the City of Broomfield. The City of Broomfield currently receives 60 percent of its water supply from Great Western Reservoir and 40 percent from the City of Denver. The City of Broomfield operates a water treatment facility immediately downstream from Great Western Reservoir, which supplies drinking water to approximately 28,000 persons. Water quality in Great Western Reservoir and the Walnut Creek drainage is routinely monitored by the RFP, the City of Broomfield, and the CDH. The City of Broomfield and CDH collect samples at the water treatment facility and below the reservoir dam (CDH, 1990b). Great Western Reservoir has met and continues to meet all federal and state drinking water standards (CDH, 1990b).

The DOE is planning to supply the residents of Broomfield with a new source of water from nearby Carter Lake. In addition, construction of the Broomfield Diversion Ditch isolates Great Western

Reservoir from the north and south branches of Walnut Creek. Broomfield residents will continue to receive their water from Great Western Reservoir and the City of Denver until the Carter Lake pipeline project is completed in 1995, at which time the DOE will take over control of the reservoir (Broomfield, 1993).

The City of Broomfield remedy acreage abuts Great Western Reservoir to the south. Existing slopes at and near the remedy acreage measure 2 to 15 percent and face to the east, allowing portions of the northernmost City of Broomfield remedy acreage to drain into Great Western Reservoir (DOE, 1992c).

2.2.3 IHSS 201 – Standley Lake

IHSS 201 includes Standley Lake, the associated drainages flowing into and out of the reservoir, and their associated sediments. The normal capacity for Standley Lake is 43,000 acre-feet and its surface area is approximately 1,200 acres (DOE, 1992b). Although approximately 96 percent of Standley Lake's water originates as snowmelt from Clear Creek (not part of the OU 3 study area) via irrigation ditches (Farmer's Highline, Croke, and Church Ditches), some water does come from Woman Creek, Smart Ditch, and Upper Big Dry Creek. The water from these latter sources consists of both in-basin natural runoff and water that is diverted from Coal Creek, which lies to the west of these two creeks.

Woman Creek runs just south of the main RFP area (Figure 2-2), through the RFP buffer zone (DOE, 1992b). Recently, RFP established a surface water control system to prevent runoff from its main production area from reaching Standley Lake. Currently, only buffer zone surface runoff and natural groundwater seepage flow into the Woman Creek drainage areas within RFP boundaries (DOE, 1992c).

From 1914 to 1966, water from Standley Lake was only used for irrigation. However, water from Standley Lake is now divided between residential use by the following three municipalities and the Farmer's Reservoir and Irrigation Company (FRICO):

- The City of Westminster owns 37.3 percent of Standley Lake Division shares
- The City of Thornton owns 13.3 percent of Standley Lake Division shares
- The City of Northglenn owns 17.7 percent of Standley Lake Division shares
- FRICO owns 31.7 percent of Standley Lake Division shares

FRICO's water shares are transported through irrigation ditches to agricultural areas northeast of the lake, primarily between Broomfield and Fort Lupton (Tipton, 1989). More than 180,000 people within the cities of Westminster, Thornton, Northglenn, and Federal Heights receive their primary drinking water from Standley Lake (DOE, 1992b). According to CDH (1990b), Standley Lake continues to meet all federal and state drinking water standards.

2.2.4 IHSS 202–Mower Reservoir

IHSS 202 consists of Mower Reservoir, the associated drainages flowing into and out of the reservoir, and their respective sediments. Mower Reservoir is located approximately 1.5 miles southeast of the RFP (and approximately 1,500 feet from the eastern RFP buffer zone boundary). The water rights to Mower Reservoir, an agricultural resource, are privately owned by a farmer in the area and the land around the reservoir is owned by Jefferson County Open Space. Mower Reservoir is used for irrigation of pasture land and water for livestock. The reservoir is fed by Woman Creek via Mower Ditch, an irrigation ditch that originates within the RFP boundary. The associated water rights decree for Mower Reservoir states that water from the reservoir was first diverted for irrigation in 1872. Mower Reservoir covers approximately 9 acres of surface area and is roughly 5 to 10 feet deep at its deepest point (DOE, 1992c).

2.3 PHYSICAL ENVIRONMENT

2.3.1 Physical Setting

The area west of the RFP is primarily mountainous, sparsely populated, public land (for example, National Forest), while the area east of the RFP is primarily a high, arid plain, densely populated to the southeast, and privately owned. The RFP is situated at an elevation of approximately 6,000 feet, (1,830 meters), above mean sea level, on the western margin of the Colorado Piedmont section of the Great Plains Physiographic Province (Fenneman, 1931). The site is located where the Colorado Piedmont is terminated abruptly by the Front Range section of the southern Rocky Mountains. The Front Range rises to elevations of 12,000 to 14,000 ft (3,660 to 4,270 m) to the west of the RFP site.

The Colorado Piedmont represents an old erosional surface along the eastern margin of the Rocky Mountains. It is underlain by gently dipping sedimentary rocks, which are abruptly upturned at the Front Range to form hogback ridges parallel to the mountain front. The piedmont surface is broadly rolling and slopes gently to the east with a topographic relief of several hundred feet (approximately 100 m). This relief is attributed both to resistant bedrock units that rise above the landscape and to incised stream drainages. Major stream valleys run predominantly from west to east in the area. Numerous local valleys from minor tributaries also exist (DOE, 1980a).

In the RFP area, a series of Quaternary pediments have been deposited across the gently rolling piedmont surface and incised by several minor drainages. The RFP is located on a relatively flat surface formed by one such pediment. The pediment has been eroded by creeks on the north and south to form a terrace that ranges in height from 50 to 150 ft (15 to 46 m). The grade of the dissected pediment surface ranges from 0.7 percent at the RFP to approximately 2 percent just east of the plant (DOE, 1990).

2.3.2 Climate

The RFP area has a semiarid climate typical of the Rocky Mountain region, characterized by dry, cool winters and warm summers. Elevation and topography of the nearby slopes of the Front Range significantly influence climate and meteorological dispersion characteristics of the site. Annual precipitation is slightly greater than 15 inches (38 cm/yr) with more than 80 percent occurring between April and September. Rainfall intensity and duration vary widely. During a hydrological study of the RFP between 1972 and 1975, rainfall intensities varied from less than 0.1 inches per hour (<0.25 cm per hour) to approximately 0.5 inch/hr (1.25 cm/hr) (USGS, 1976a). The total number of days per year that precipitation is greater than 0.1 inches is approximately 47.

Area temperatures are moderate; extremely hot or cold weather typically is of short duration. Maximum and minimum temperatures average 76 and 22°F. Average summer temperatures range from 55 to 85°F, or 13 to 29°C, while winter temperatures range from 20 to 45°F (DOE, 1980a). The growing season, based on the last spring freeze to the first autumn freeze (of temperatures 32°F and colder), is approximately 148 days per year (Doesken, 1993). Snowfall averages 85 inches/year (216 cm/yr) (DOE, 1980a). Soil is generally frozen from approximately the last week in November to the first or second week of March (Doesken, 1993).

Winds, though variable, are predominantly north-westerly. Stronger winds occur during the winter months, and the area occasionally experiences gusts in excess of 100 miles per hour. The general annual wind pattern (Figure 2-3) for RFP illustrates that winds are predominantly from the northwest quadrant approximately 46 percent of the year. Outside of the northwest quadrant, the next largest wind rose component is due to wind from the west-southwest, which occurs approximately 7.2 percent of the year. The highest velocity winds (> 15 meters per second [m/s]) (> 34.5 miles per hour [mph]) are generally from the west-northwest and west. Topographic conditions specific to OU 3 may cause local variations in wind direction; however, the annual averages are not expected to significantly differ from those for the entire RFP site. Based on the above information, the general

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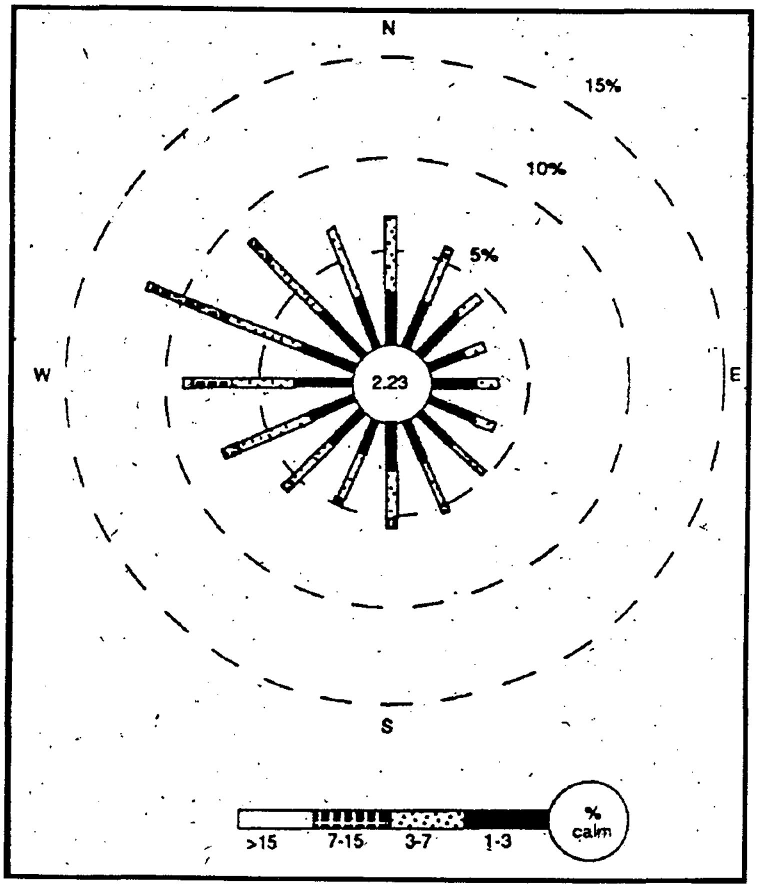


SOURCE: RFP Site Environmental Report for 1991

Figure 2-3
RFP 1991 WIND ROSE
24-HOUR

area from the east-northeast to the south and southeast of the RFP could receive the largest deposition of particulates from the RFP (DOE, 1992c).

2.3.3 Geology

The RFP is situated on the Rocky Flats Alluvium, which is a gravelly alluvial fan deposit, varying in thickness from 0 to 100 feet over the bedrock. Underlying bedrock formations consist primarily of claystone with some siltstones. Seismic activity of the area is low, and landslide potential and subsidence because of earthquakes are not considered likely at the RFP (DOE, 1980a).

Surficial deposits in the RFP area consist of unconsolidated Quaternary-age units, which unconformably overlie the Arapahoe Formation and other subcropping bedrock units. The RFP is located on a terrace capped by Rocky Flats Alluvium. The Rocky Flats Alluvium is a series of laterally coalescing fans deposited by streams. Bedding is uncommon. The unit consists of sand, clay, silt, gravel, cobbles, and occasional boulders, and is weakly to moderately cemented with caliche (calcium carbonate) in some areas.

Below the Rocky Flats Alluvium are the Verdos and Slocum Alluviums. These deposits consist largely of drainage infilling with reworked Rocky Flats Alluvium. In addition, active deposition of valley fill alluvium is occurring within existing drainages in the RFP area (DOE, 1990).

2.3.4 Surface Water

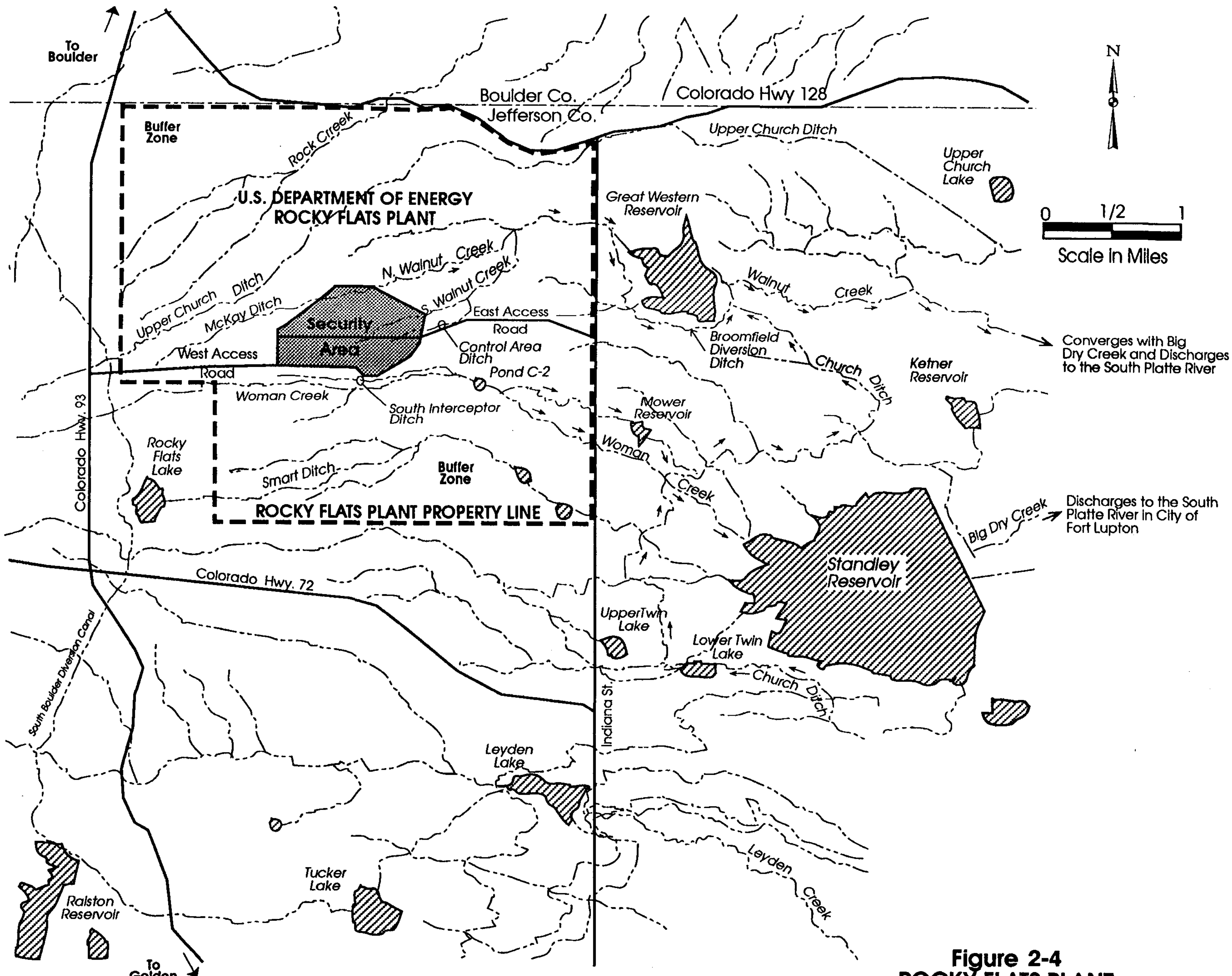
Several ephemeral streams flow through the RFP area. Three of these streams (North Walnut Creek, South Walnut Creek, and Woman Creek) originate within the RFP boundary and flow generally eastward from the plant site. The Walnut Creek and Woman Creek drainages within the boundary of the RFP are being investigated under the IAG as OU 5 and OU 6, respectively. A fourth ephemeral stream, Rock Creek, originates in the Buffer Zone northwest of the main production facility and flows northeast from the RFP. Rock Creek drains the northeast corner of the

RFP and flows northeast through the RFP buffer zone to its confluence with Coal Creek (outside of the OU 3 study area). Rock Creek was selected to represent background conditions for surface water drainages and sediments in the 1992 Background Geochemical Characterization Report (DOE, 1992d). Other surface water features in the vicinity of the plant include a complex network of manmade diversions and impoundments. RFP surface water features are shown in Figure 2-4. Flow into and within these features results from direct surface runoff, baseflow from groundwater, and diversions and wastewater from human-related activities. A sitewide study of the hydrology of the RFP determined that surface runoff in the Woman Creek basin averages only 1.4 percent of rainfall, indicating either a high soil infiltration rate or high surface retention capacity. This study was based on records for long-duration, low-intensity precipitation; runoff may be much higher for a short-duration, high-intensity event (USGS, 1976).

2.3.5 Groundwater

Two groundwater systems exist in the RFP area: an unconfined system, which is present in saturated surficial deposits (the upper hydrostratigraphic unit) in many areas of the RFP, and a confined system in claystones and sandstones of the underlying Arapahoe Formation (the lower hydrostratigraphic unit) (USGS, 1976). The shallow unconfined system is recharged by infiltration from incident precipitation and from surface and baseflow water (such as drainages and reservoirs). Groundwater flow is generally to the east and toward drainages. Groundwater flow is locally controlled by topography and discharges as seeps or springs in drainages, especially where the surficial deposit/bedrock contact is exposed such as subcropping sandstone channels. Large water table fluctuations may occur in the shallow system in response to seasonal variations in recharge and discharge, with the highest water levels generally occurring during the months of May and June and the lowest water levels generally occurring in January and February. As a result of these fluctuations, the lateral and vertical extent of saturated surficial deposits varies seasonally.

Confined groundwater in the lower hydrostratigraphic unit exists primarily in lenticular sandstone bodies within claystone. Groundwater flow in the upper hydrostratigraphic unit occurs in the



Source: DOE, 1991a

Figure 2-4
ROCKY FLATS PLANT BOUNDARIES AND BUFFER ZONE

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unconsolidated Quaternary surficial deposits and the shallow sandstone within the bedrock. Recharge to this unit consists of infiltration from streams and precipitation. The lower hydrostratigraphic unit is found in the deeper bedrock sandstones, which exhibit confined conditions and limited connections with the unconfined system. Recharge to this unit occurs primarily from baseflow and leakage from the overlying claystone. Groundwater in the lower hydrostratigraphic unit flows east toward a regional discharge area along the South Platte River, some 20 mi (32 km) east of the RFP. Calculated horizontal linear flow velocities for the system average 0.1 ft/day (0.03 m/day) in the sandstones and approximately 9×10^{-4} ft/day (2.7×10^{-4} m/day) in the claystone (USGS, 1976; Hydro-Search, 1985).

Section 3
LAND USE IN THE OU 3 STUDY AREA

3.0 LAND USE IN THE OU 3 STUDY AREA

Section 3.0 identifies the current and potential future land uses and population data for the OU 3 study area. This information is based on available data from cities and counties in the OU 3 study area. Identifying current and potential future land uses is a necessary step in the process of developing site-specific exposure scenarios. The exposure of people to site contaminants depends on the type of land use (such as residential, recreational/open space, agricultural, or commercial/ industrial uses). A typical commercial/industrial exposure scenario, for example, would define the activities of persons working in an area currently zoned for commercial/industrial use and present a realistic snapshot of their activities. This scenario would differ from the exposure activities of people living in a residentially zoned area.

The 1989 Population, Economic, and Land Use Data for the Rocky Flats Plant (DOE, 1990) demographics report presents land use and population data for the areas within 50 miles of the RFP. Based on that report, Figure 3-1 portrays the 1989 population estimates and household numbers within a 10-mile radius of the RFP. The area of Figure 3-1, including Sectors 3 through 5 and pie sections P through J (clockwise), is a general estimate of the population in the OU 3 study area. Sectors 1 and 2 are not considered part of the OU 3 study area because those sectors lie within RFP boundaries. Table 3-1 is a summary of the sectors and the associated sections (P through J, clockwise) that are pertinent to the OU 3 study area for 1989, 2000, and 2010.

As shown by the 1989 numbers (from Figure 3-1) a direct relationship exists between the distance from RFP and population growth, with the greatest population growth seen in Sector 5. The population trends exhibited in Figure 3-1 correlate with the land uses in these areas, which is addressed in Subsection 3.1.

TABLE 3-1

SUMMARY OF POPULATION SECTORS IN THE OU 3 STUDY AREA

Sector	1989 Population	1989 Household No.	2000 Population	2000 Household No.	2010 Population	2010 Household No.
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	51	15	51	15	51	17
4	633	193	1,486	590	2,263	950
5	8,439	2,508	16,471	6,337	23,773	9,957
10	307,567	109,859	331,325	141,598	408,821	171,141

Figure 3-2 presents the projected populations and household numbers for the year 2000 within a 10-mile radius of the RFP. Again, the pertinent sectors and sections for the OU 3 study area are given in the table above. There is no change in population or household number for Sector 3. However, an increase is seen in Sector 4 population from 633 in 1989 to 1,486 in 2000. A greater population growth is exhibited in Sector 5 where in 1989, the population was 8,439 and the projected 2000 population is 16,471. The trends shown in Table 3-1 (and Figure 3-1) accompany future land use patterns, which are discussed in Subsection 3.2.

Projected populations and household numbers for the year 2010 are shown in Figure 3-3. Trends in Figure 3-3 reflect those of the 2000 projections (Figure 3-2) in that there is population growth in Sector 4 from 1,486 in 2000 to 2,263 in 2010. The 2010 population projection for Sector 5 is a significant increase from 8,439 in 1989 to 16,471 in 2000 and finally 23,773 in 2010. This population growth parallels the projected urban development for that area.

Subsection 3.3 discusses the land uses immediately outside of the OU 3 study area to identify possible changes in land use that could affect OU 3, or changes within OU 3 that could affect land use and population in areas outside the OU 3 study area.

The following major documents and maps were acquired and used as the basis for the information presented in this section:

- City of Arvada Official City Map (Arvada, 1992)
- City of Broomfield Zoning Map (Broomfield, 1990)
- City of Broomfield Master Plan (Broomfield, 1988)
- 1989 Population, Economic, and Land Use for Rocky Flats Plant, Golden, Colorado (DOE, 1990a)

- Final Past Remedy Report, Operable Unit No. 3–IHSS 199 (DOE, 1991a)

- Final Historical Information Summary and Preliminary Health Risk Assessment, Operable Unit No. 3–IHSS 200-202 (DOE, 1991b)

- Environmental Assessment Standley Lake Diversion Project (DRAFT) (DOE, 1992b)

- 2010 Regional Transportation Plan (DRCOG, 1987)

- W-470 Corridor Study, Final Report (DRCOG, 1988)

- Rocky Flats Plant Site Environmental Report for 1991 (EG&G, 1991b)

- Northeast Land Use Inventory, Jefferson County (JEFFCO, 1989a)

- Jefferson County Airport Master Plan (JEFFCO Airport, 1988)

3.1 CURRENT LAND USES WITHIN THE OU 3 STUDY AREA

The OU 3 study area is defined in Subsection 2.2 (Figure 2-2) as encompassing the four IHSSs of OU 3, however, the study area may be redefined as a result of ongoing investigations. This subsection describes the current land uses for the four IHSSs defined in Subsection 2.2. Figure 3-4 illustrates the current land uses for the OU 3 study area.

In addition, two bald eagles have been sighted in an area southeast of the 100th Avenue and Alkire intersection near the Church Ditch drainage in the OU 3 study area. The U.S. Fish and Wildlife service believes that the bald eagles (an endangered species) are nesting in that area. The nesting of an endangered species in the area will affect risk management decisions, which will most likely impact zoning and development decisions.

3.1.1 Soils (IHSS 199)

As currently defined, IHSS 199 includes soils outside of the RFP boundary as shown in Figure 2-2 (IAG, 1991). Current land uses (residential, commercial/industrial, recreational/open space, and agricultural) of the surface soil area (IHSS 199) in the OU 3 study area are discussed in the following land use subsections.

3.1.1.1 Current Residential Land Use of IHSS 199

The majority of the current residential development in IHSS 199 is located northeast, east, south, southeast, and southwest of Standley Lake Reservoir as shown in Figure 3-4. Commercial/industrial and residential land uses are interspersed in the developments northeast and southwest of Standley Lake, including an area north of the Jefferson County Airport (north of U.S. 36, the Boulder Turnpike). Smaller residential land use areas are located west of Standley Lake between Woman Creek and Smart Ditch, in the vicinity of Upper Twin Lake, and along Highway 72 in the southwest corner of the OU 3 study area.

3.1.1.2 Current Commercial/Industrial Land Use of IHSS 199

Commercial and industrial development is currently concentrated near the residential developments north and southwest of Standley Lake and in the proximity of the Jefferson County Airport, which is located approximately 5 miles northeast of the RFP, south of Colorado Highway 128 between Simms Street and Colorado Highway 121 (Figure 3-4). To the immediate north of the Jefferson County Airport, vacant/undeveloped/rangeland and a light-industrial business park adjoins the airport property. Farther north of the airport (beyond Colorado Highway 36), residential and commercial/industrial land uses exist in conjunction with the central business district of the City of Broomfield. Major commercial facilities in the Jefferson County Airport area include the Ball Corporation office complex, and the Interlocken business park (JEFFCO Airport, 1988).

There is also a commercial/industrial land use area located in the southwest corner of IHSS 199, directly south of the RFP along Colorado Highway 72. Developments include the TOSCO Laboratory, Great Western Inorganics Plant, and Frontier Forest Products (EG&G, 1991a).

3.1.1.3 Current Recreational/Open Space Land Use of IHSS 199

The largest areas of IHSS 199 used for recreational/open space purposes are open space properties located along the northern and southern shores (and the adjoining property) of Standley Lake, also known as Standley Lake Park (Figure 3-4). Since 1970, the area in the immediate vicinity of Standley Lake has been managed by the City of Westminster as a park. In the mid-1970s, Jefferson County Open Space funds were used by Jefferson County to acquire 464.5 acres of land bordering the lake. The recreational activities available at Standley Lake Park and associated with the land surface (surface soil) include hiking, biking, camping, and picnicking (Standley Lake Task Force, 1990). People using Standley Lake Park are likely to contact both the soil (IHSS 199) and Standley Lake water and sediment (IHSS 201).

A large area classified as open space is located between Great Western Reservoir and Standley Lake, including the Walnut Creek drainage and the Church Ditch drainage (DOE, 1990). This open space surrounds Great Western Reservoir, although access to the reservoir via public roads has been restricted with a perimeter fence since 1971 by the City of Broomfield, the owner of Great Western Reservoir. The open space outside of the Great Western Reservoir fence is partially fenced and posted and is not easily accessible to the public. Consequently it is not an area used for recreational purposes (CDH, 1992b). The City of Broomfield purchased 80 acres of open space north of Great Western Reservoir up to Colorado Highway 128. The open space south of the reservoir is owned by Jefferson County, and the open space east and west of the reservoir are owned by private developers and the DOE, respectively (Broomfield, 1993).

Another open space area is located in the northwest corner of the OU 3 study area north of Colorado Highway 128 and west of Indiana Street (DOE, 1990). This open space area is similar to the open space described near Great Western Reservoir. This area has restricted public access and is therefore not readily utilized for recreational purposes. The residential developments north of Standley Lake Reservoir contain several areas of open space that are most likely used for recreational purposes by the local residents.

3.1.1.4 Current Agricultural Land Use of IHSS 199

There are only three parcels of land currently used for agricultural purposes in IHSS 199. The land designated as agricultural in Figure 3-4 is primarily rangeland used for horse-boarding operations and cattle grazing as well as alfalfa production to feed these animals (JEFFCO, 1993). The first is located in the northwest corner of the OU 3 study area north of Colorado Highway 128 and west of Indiana Street. Cattle grazing, horse boarding, and the growing of alfalfa, wheat, barley, corn, and oats are known to occur in this area (DOE, 1990). The second designated agricultural area is located south of the Jefferson County Airport just east of Simms Street. Agricultural land utilization of this area includes horse boarding and the growing of wheat and barley. The third area is located southeast of the RFP, north of Upper Twin Lake (DOE, 1990). Many horse-boarding operations have been observed in this area, as well as the production of alfalfa (RA Consultants, 1993).

3.1.2 Great Western Reservoir (IHSS 200)

IHSS 200 consists of Great Western Reservoir and the drainages leading into and out of the reservoir and the associated sediments. Discussed briefly below are the current land uses involved with the Great Western Reservoir IHSS.

3.1.2.1 Current Residential Uses of IHSS 200

Great Western Reservoir is currently the primary water source for City of Broomfield residents. The water from Great Western Reservoir is processed through the Broomfield water treatment plant, where it is treated and monitored for radionuclides on a routine basis. The water from Great

Western Reservoir has met and continues to meet the federal maximum contaminant levels as promulgated by the EPA and the Colorado Primary Drinking Water Regulations (EG&G, 1990b).

3.1.2.2 Current Commercial/Industrial Uses of IHSS 200

There is no commercial/industrial land use of the Great Western Reservoir. Walnut Creek drainage flows through a small section of land for commercial/industrial land use located west of Colorado Route 121 south of the JEFFCO Airport.

3.1.2.3 Current Recreational/Open Space Uses of IHSS 200

Access to Great Western Reservoir has been limited since at least 1971, when a fence was constructed restricting entry via public road (CDH, 1992b). Since then, recreational activities such as fishing, boating, swimming, and wading have not been permitted because of this restricted access to the area.

3.1.2.4 Current Agricultural Uses of IHSS 200

Great Western Reservoir is currently not an agricultural water supply (Broomfield, 1993). However, Walnut Creek and Church Ditch, which flow southeast of Great Western Reservoir, are used for irrigation of crop land.

3.1.3 Standley Lake (IHSS 201)

IHSS 201 includes Standley Lake and the associated drainages flowing in and out of the reservoir, and their respective sediments. Current usages are discussed in the following subsections.

3.1.3.1 Current Residential Use At IHSS 201

Currently, there are no residences on the shores of Standley Lake. There are residential developments in the proximity of Woman Creek and Smart Ditch (to the west), and Big Dry Creek flowing out of Standley Lake. These are discussed in Subsection 3.1.1.1. However, Standley Lake is designated as a public water supply (DOE, 1990). The water from Standley Lake is treated and continues to meet federal maximum contaminant levels at promulgated by EPA, as well as the Colorado Primary Drinking Water Regulations (EG&G, 1990b).

3.1.3.2 Current Commercial/Industrial Use at IHSS 201

There is no commercial/industrial land use at Standley Lake or its associated drainages.

3.1.3.3 Current Recreational/Open Space Use at IHSS 201

Since 1970, the Standley Lake and the immediate vicinity has been managed by the City of Westminster as a park (Standley Lake Task Force, 1990). In the mid-1970s, Jefferson County Open Space funds were used by Jefferson County to acquire 464.5 acres of land around the lake, including its shoreline. Park visitation records kept by the Westminster Parks and Recreation Department indicate that approximately 52,000 to 72,000 people visited Standley Lake annually over the 5-year period from 1988 to 1992 to boat, water ski, sailboard, camp, picnic, wade, or fish. The people who visit Standley Lake Park are likely to contact both the soils IHSS (199) and the Standley Lake water and sediment (IHSS 201).

3.1.3.4 Current Agricultural Use at IHSS 201

A portion of the water from Standley Lake Reservoir is currently used for irrigation.

3.1.4 Mower Reservoir (IHSS 202)

IHSS 202 consists of Mower Reservoir, the associated drainages flowing in and out of the reservoir, and their respective sediments. The current land uses for Mower Reservoir are discussed below.

3.1.4.1 Current Residential Uses of IHSS 202

Mower Reservoir is not a public water supply and there are no residential land uses on Mower Reservoir or its associated drainages.

3.1.4.2 Current Commercial/Industrial Uses of IHSS 202

There are no developments of this type within the Mower Reservoir area, nor are there any commercial/industrial facilities that receive water from this reservoir.

3.1.4.3 Current Recreational/Open Space Uses of IHSS 202

Mower Reservoir is privately owned; public recreational use of the reservoir is not allowed.

3.1.4.4 Current Agricultural Uses of IHSS 202

Mower Reservoir water is used to irrigate the pasture land and water the livestock of the farmer who owns it (RA Consultants, 1993).

3.2 POTENTIAL FUTURE LAND USES WITHIN THE OU 3 STUDY AREA

This section describes the potential future land uses for the four IHSSs in the OU 3 study area. Future land use is based on the information from local and county planning and zoning agencies and documents (listed in Section 3.0), however, rezoning of an area may occur in the future.

A summary of future land use in the OU 3 study area is shown in Figure 3-5. In general, future land use in this area may include the following land uses:

- Residential
- Commercial/Industrial
- Agricultural
- Recreational/open space and parks

3.2.1 Soils (IHSS 199)

All of the above land uses are anticipated to occur in the OU 3 study area and are discussed in the following subsections.

3.2.1.1 Future Residential Land Use of IHSS 199

The 1989 Population, Economic, and Land Use for the Rocky Flats Plant (DOE, 1990) report addresses the population trends expected in the OU 3 study area. According to the report, the population of the area that includes the OU 3 study area is expected to grow from its estimated 1989 population of 9,123 to 18,008 by the year 2000 and 26,078 by 2010. A large area of future residential growth is projected around the perimeter of the Standley Lake Park, where a trend of building to closeout densities is predicted. The primary growth in residential development is projected for the land west of Standley Lake and east of Indiana Street, an area which is currently vacant/undeveloped/rangeland (DOE, 1992b).

3.2.1.2 Future Commercial/Industrial Land Use of IHSS 199

One of the areas within the soils (IHSS 199) study area to undergo a significant growth in development is the land in the immediate vicinity of the Jefferson County Airport. The City of Westminster has identified the land within its corporate limits that abuts Jefferson County Airport as an "Employment Center." The following developments are encouraged in this area: office parks, shopping centers, office/warehouse complexes, quality restaurants, athletic clubs, research laboratories, and scientific manufacturing facilities (JEFFCO Airport, 1988). The commercial/industrial land use in the vicinity of the Jefferson County Airport is predicted to expand (Figure 3-5) to the west and south as compared to the current land use in that area (Figure 3-4). The land east and north of the airport in the section of land between the airport and U.S. Highway 36 (the Boulder Turnpike) is proposed commercial/industrial development. Directly southwest of the Jefferson County Airport lies an area of land (currently open space [Figure 3-4] with a limited commercial development), that is projected to contain a mix of land uses in the future, including commercial uses.

There are several land areas listed below that are predicted to change from their current residential, open space, agricultural, or vacant/undeveloped/rangeland land use classification to commercial uses in the future:

- The land north of Colorado State Highway 128 (currently vacant, undeveloped rangeland)
- The land directly east of Standley Lake
- The land including most of the southwest corner of the OU 3 study area

3.2.1.3 Future Recreational/Open Space Land Use of IHSS 199

The largest anticipated change in land surface regarding recreational/open space use is the addition to Standley Lake Park. Figure 3-5 shows more land in the Standley Lake area being dedicated to park and open space land use compared to the current map (Figure 3-4). The Standley Lake Task Force is currently considering the transformation of the Standley Lake area into a state park that would be managed by the Colorado Division of Parks and Outdoor Recreation

(DOE, 1992b). The park would help alleviate the burden of high recreational demands placed on the Cherry Creek and Chatfield State Recreation Areas. The task force envisions a water-based recreational/open space area that will provide shelters and restrooms, volleyball and tennis courts, a marina for boats, an isolated swim beach, and designated hiking, biking, and equestrian trails. Current planning will affect both IHSS 199 and 201. Negotiations between the City of Westminster, Jefferson County, and the Colorado Division of Outdoor Recreation are currently underway (DOE, 1992b) to decide the fate of Standley Lake Park.

A reduction in current open space between Great Western Reservoir and Standley Lake is predicted because of the proposed residential and commercial/industrial development in that area (Broomfield, 1991). However, the open space area in the immediate vicinity of Great Western Reservoir is projected to remain open space with a less restricted access to the area for recreational/open space purposes. According to the Parks, Open Space, and Trails Map in the City of Broomfield Master Plan (Broomfield, 1988), Great Western Reservoir and the area surrounding the reservoir are to remain open spaces with the addition of a proposed hiking trail which would leave the eastern edge of the reservoir and continue along or near Walnut Creek and Dry Creek Valley to Simms Street.

3.2.1.4 Future Agricultural Land Use of IHSS 199

Currently, available land use and development documents indicate a decline in large-scale parcels of land zoned for agricultural use (CDA, 1993). As shown in the future land use map (Figure 3-4), there are no zoned land areas for agricultural use proposed for the future in the OU 3 study area (DOE, 1990).

3.2.2 Great Western Reservoir (IHSS 200)

Great Western Reservoir is currently a primary municipal water supply for the City of Broomfield and will be until 1995, when a pipeline from Carter Lake is scheduled to be in place to supply residents of Broomfield with a new drinking water source (Broomfield, 1993). The DOE will manage Great

Western Reservoir; DOE does not have a development or management plan for the reservoir at this time (Broomfield, 1993). The possibility of draining Great Western Reservoir has not been excluded.

The future of Great Western Reservoir may be affected by flood control agreements between the Urban Drainage and Flood Control District (UDFCD) and the cities of Broomfield and Westminster (Agreement No. 87-02.02, 1987). Prior to the decision by the DOE to obtain a new water supply for the City of Broomfield, there were plans to expand Great Western Reservoir from 3,250 acre-feet to 12,500 acre-feet. Had the City of Broomfield completed this expansion, the 1987 agreement stated that the UDFCD and the City of Westminster would have maintained the flood control capabilities of Great Western Reservoir. However, the expansion did not occur, and therefore, maintenance of the flood control capabilities by the cities of Broomfield and Westminster and the UDFCD is not required. If the draining of Great Western Reservoir does occur, there are currently no restrictions on future land use for the former reservoir land area, and consequently, the area could be designated any land use in the future, including residential, commercial/industrial, recreational/open space, or agricultural.

The future use of Great Western Reservoir is uncertain. However, one of the options for Great Western Reservoir after 1995, when the new water supply from Carter Lake is scheduled for the City of Broomfield, includes draining the reservoir.

3.2.2.1 Future Residential Land Use of IHSS 200

If Great Western Reservoir is drained, there is a possibility that residential development could occur on the former reservoir bottom. If drainage of Great Western Reservoir for residential development occurs, it is likely that the reservoir bottom will be filled in with gravel and dirt. Residential development along Walnut Creek just east of Great Western Reservoir is projected to increase in an area that is currently designated as open space.

3.2.2.2 Future Commercial/Industrial Land Use of IHSS 200

Unless Great Western Reservoir is drained, it is unlikely that development would occur on the shores of the reservoir. Development along the Great Western Reservoir drainages (Walnut Creek and Church Ditch) is proposed in an area directly east of the reservoir and west of Simms Street (Broomfield, 1991).

3.2.2.3 Future Recreational/Open Space Land Use of IHSS 200

There are no guidelines in place at this time limiting the future recreational/open space use of Great Western Reservoir. The reservoir may be available to the public for future recreational/open space purposes in its present condition or possibly even if it is drained. A hiking trail that would leave the eastern edge of Great Western Reservoir and continue along Walnut Creek to Simms Street has been proposed (Broomfield, 1988).

3.2.2.4 Future Agricultural Land Use of IHSS 200

Currently, available land use and development documents indicate a decline in large-scale parcels of land zoned for agricultural use (CDA, 1993; DOE, 1990) Therefore, even if Great Western Reservoir is drained, it is unlikely that the former reservoir would be transformed into agricultural land. As presented in Figure 3-5, there are no land areas zoned for future agricultural uses on Great Western Reservoir or any of its associated drainages. However, water flowing in Walnut Creek and Church Ditch southeast of the reservoir may continue to support downstream agricultural uses.

3.2.3 Standley Lake (IHSS 201)

The Standley Lake Diversion Project has been initiated to protect drinking water by detaining and diverting Woman Creek through a diversion canal (or pipeline). Also included in the project is the construction of a detention reservoir with a 100-year event capacity between the RFP and the diversion canal, a pipeline or ditch improvements to reroute Coal Creek water deliveries to Standley Lake, a pump/pipeline system to transfer water from Woman Creek to Walnut Creek, and some onsite RFP water treatment systems (DOE, 1991c).

The consequences of the Standley Lake Diversion Project and the proposed Standley Lake State Park to the future land uses in the Standley Lake study area (IHSS 201) are discussed in the sections below.

3.2.3.1 Future Residential Land Use of IHSS 201

Because of the proposed Standley Lake State Park and the presence of the current park around the lake, residential development is not expected to occur on the shores of Standley Lake. However, residential development is projected in the immediate vicinity of the drainages leading to Standley Lake (Woman Creek and Smart Ditch) and the drainage leaving the lake (Big Dry Creek).

3.2.3.2 Future Commercial/Industrial Land Use of IHSS 201

There is no expected commercial use of the waters of Standley Lake. Commercial/industrial and mixed land use is expected along the drainages flowing into and out of Standley Lake (JEFFCO, 1989d).

3.2.3.3 Future Recreational/Open Space Land Use of IHSS 201

As discussed in Subsection 3.2.1.3, significant change in the Standley Lake area regarding recreational/open space use is the addition to Standley Lake Park. Figure 3-5 shows more land in the Standley Lake area being dedicated to park and open space land use compared to the current map (Figure 3-4). Recreational/open space use of the land in close proximity of the Standley Lake drainages (Woman Creek, Smart Ditch, and Big Dry Creek) is also expected to increase because of the growth in residential development along those drainages (DOE, 1992b; JEFFCO, 1989d).

3.2.3.4 Future Agricultural Land Use of IHSS 201

Future use of Standley Lake Reservoir as an irrigation water source is expected to continue. Agricultural land use of Standley Lake and its associated drainages, however, is not projected (DOE, 1992b).

3.2.4 Mower Reservoir (IHSS 202)

Because Mower Reservoir is currently a privately-owned reservoir, its future is uncertain. The primary utilization of Mower Reservoir water is for agricultural land purposes. The potential future land use options for Mower Reservoir and its associated drainages are presented in the following sections.

3.2.4.1 Future Residential Land Uses of IHSS 202

Current nonresidential land use is expected to continue for the foreseeable future. However, residential development is possible along Mower Reservoir drainages to the east should the property assume new ownership (DOE, 1992b; JEFFCO, 1989d).

3.2.4.2 Future Commercial/Industrial Land Uses of IHSS 202

The proposed uses for the land abutting Mower Reservoir on its eastern border (including its drainages) are occupational and residential (DOE, 1992b).

3.2.4.3 Future Recreational/Open Space Land Uses of IHSS 202

Open space is predicted for the land in the immediate vicinity of Mower Reservoir to the north, west, and south (DOE, 1992b).

3.2.4.4 Future Agricultural Land Uses of IHSS 202

Currently, Mower Reservoir is privately-owned and is solely used for agricultural purposes such as irrigation and water for livestock. No change is expected in the future land use of this reservoir (DOE, 1992c).

3.3 FUTURE LAND USES AND CONCERNS OUTSIDE THE OU 3 STUDY AREA

There are several potential future land use developments and concerns outside the OU 3 study area that may impact the OU 3 study area including the Jefferson Center Metropolitan District, the W-470 freeway, and expansion of the Jefferson County Airport. A brief summary of each of these potential developments is presented in the subsections below.

3.3.1 Jefferson Center Metropolitan District

The Jefferson Center Metropolitan District includes business park/retail/commercial/residential/open space land use proposed for the area of land southwest of the RFP and bordered on the north by Colorado Highway 73 and on the east by Colorado Highway 93 (Jefferson, 1989d). This proposed development is similar in nature to the Denver Technological Center located south of Denver in Englewood. A development of this type could have some impact on the OU 3 study area by leading to other development in the area. However, the degree and type of additional development in the area south of the RFP cannot be identified at this time.

3.3.2 W-470 Freeway

A second development that could affect the OU 3 study area is the proposed construction of the W-470 freeway. There are several alternatives for the alignment of W-470 within the RFP area as shown in Figure 3-6 (DRCOG, 1988). One alternative would align the freeway west of the RFP. Another alternative aligns W-470 east of the RFP, west of Standley Lake, and east of Great Western Reservoir. However, the construction of W-470 is not projected for the near future; near-term development of the freeway projected over the next 5 years is unlikely (JEFFCO, 1989b).

Assuming the W-470 freeway is constructed, land use development (residential, commercial/ industrial, and recreational/open space) is expected to accompany the freeway development. Alignment of W-470 to the east of the RFP will affect the OU 3 study area to a greater extent than will a western alignment of the highway. As noted above, the eastern alignment of W-470 places the road directly through segments of OU 3.

3.3.3 Jefferson County Airport Expansion

There is a possibility that the Jefferson County Airport may undergo an expansion primarily to the north and west (JEFFCO Airport, 1988). If this expansion occurs, the land uses in the immediate vicinity of the airport may change as well. Colorado Highway 128 would be re-routed to the north, Simms Street would be re-routed to the northwest, the unclassified area of land just west of the airport may be acquired by the airport, and land north of Colorado Highway 128 may experience changes in its designated land use as shown in Figure 3-6.

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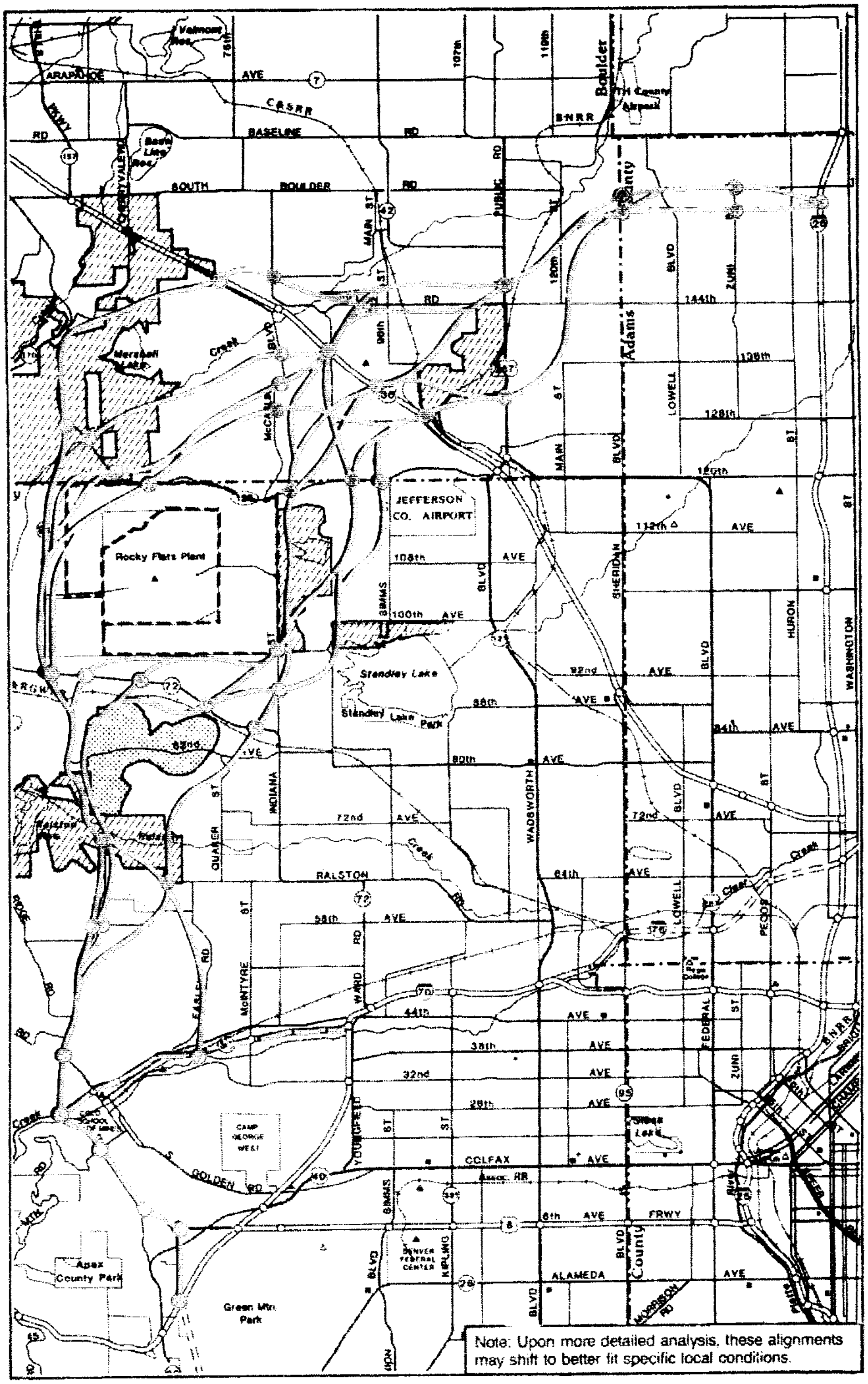

Source: DRCOG, 1988

Legend

Acquired Open Space

Leyden Gas Storage Facility

Potential Alignment

Interchange

Figure 3-6
PRELIMINARY ALTERNATIVE ALIGNMENTS FOR W-470

Section 4
EXPOSURE SCENARIOS

4.0 EXPOSURE SCENARIOS

4.1 INTRODUCTION

This section develops the scenarios to be used in assessing potential exposure to site-related COPCs under current and future residential, commercial/industrial, recreational, and agricultural land use conditions discussed in Section 3.0. The potential for exposure is defined by the complete pathways and routes through which people may contact COPCs. The exposure scenarios are based on the physical setting described in Section 2.0, and the land uses and populations as described in Section 3.0. A conceptual site model is used to identify the potential human exposure pathways for the media of concern for OU 3.

An exposure pathway is the means by which a person (receptor) may come into contact with contaminants in a given environmental medium. A complete pathway has six elements:

1. Contamination source
2. Mechanisms for contaminant release
3. Environmental transport medium
4. Exposure point
5. Route of exposure
6. Receptors available

A pathway must be complete for the potential of exposure to exist (EPA, 1991b). The exposure scenarios are then determined by placing these pathways in the context of current and future land use and activity patterns.

Subsection 4.2 presents the conceptual site models and the priority human exposure pathways for OU 3 based on information presented in the RFI/RI Work Plan for OU 3 (Work Plan) (DOE, 1992c). Subsection 4.3 describes the general characteristics of exposure for the land uses described in Section 3.0. Subsections 4.4 through 4.7 discuss the exposure scenarios that have been developed based on the current and future land use conditions presented in Section 3.0, the conceptual site models, and the human exposure pathways previously described in the Work Plan (DOE, 1992c). Subsection 4.8 summarizes complete and incomplete exposure pathways for OU 3.

4.2 CONCEPTUAL SITE MODELS

The conceptual site models (CSMs) provide a source characterization and an overview of the potential pathways that may result from releases or transport to each medium. Some of the pathways in a given CSM have a higher potential for occurrence than others. The CSMs were presented in the Work Plan (DOE, 1992c). The Work Plan contains an evaluation of the fate and mobility of the COPCs in each potential source area. The Work Plan also describes environmental transport media included in the conceptual models and in the Final Past Remedy Report (DOE, 1991a), and the Final Historical Information Summary Report and Preliminary Health Plan Risk Assessment (DOE, 1991b). The Final Past Remedy Report (DOE, 1991a) presents a preliminary hypothetical human health risk assessment for surface soils (IHSS 199), using assumed soil concentrations of plutonium. Similarly, the Final Historical Information Summary and Preliminary Health Risk Assessment (DOE, 1991b), presents a preliminary hypothetical human health risk assessment of IHSSs 200-202 (the OU 3 reservoirs), to evaluate surface water and sediments using assumed concentrations of plutonium in sediments. The two risk assessments were used to refine the OU 3 Work Plan (DOE, 1992c), which identifies the primary exposure pathways for OU 3.

4.2.1 Conceptual Site Model for the IHSS 199

Figure 4-1 is the general CSM of IHSS 199. The most likely complete exposure pathways are illustrated in Figure 4-2, IHSS 199 (Soils) Human Health Priority Pathways. From preliminary screening,

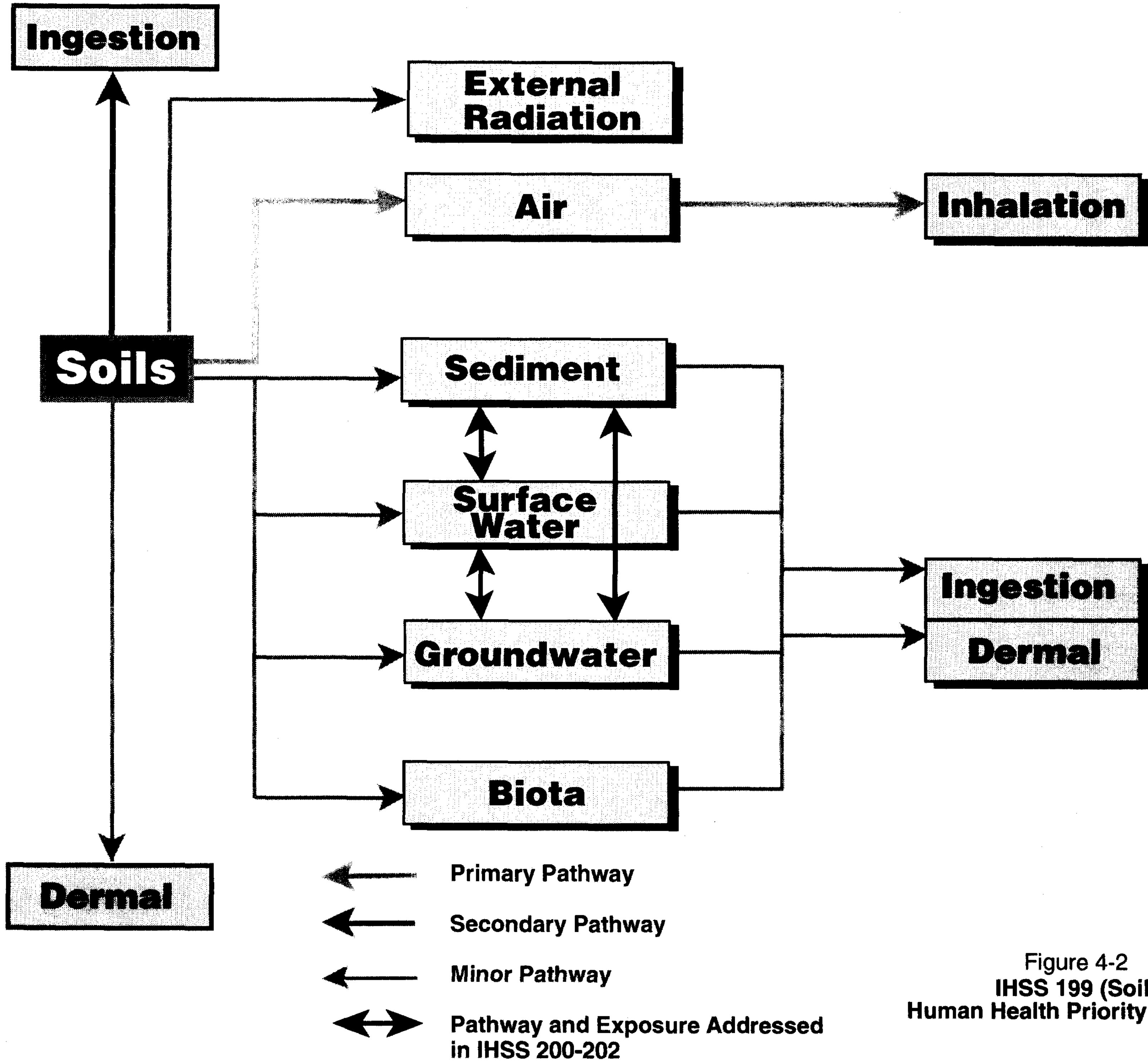

Figure 4-2
IHSS 199 (Soils)
Human Health Priority Pathways

DRAWN BY	H. DOUVILLE	CHECKED BY	P. Smith	03/09/93	DRAWING NUMBER
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the primary exposure pathway appears to be inhalation of soil particulates dispersed to air through wind erosion. Additional pathways of importance may be the ingestion of soil. The remaining pathways of ingestion of and dermal contact with sediment, surface water, groundwater, and biota appear to have a lower potential for exposure to site-related COPCs than the first two pathways (DOE, 1992c). The prioritization process used to rank the likelihood of each pathway is presented in detail in the Work Plan (DOE, 1992c) and is based on chemical characteristics in the soil, fate and mobility of particulates in air and surface water, and uptake by biota. This preliminary ranking does not consider specific toxicity of the COPCs nor estimates of potential risk. Each pathway in Figure 4-2 is presented in detail in Appendix A of the Work Plan (DOE, 1992c). The following is a brief summary of information originally presented in the Work Plan (DOE, 1992c) explaining the conceptual model and pathways for soils.

Plutonium and americium are the only site-related COPCs observed in the OU 3 surface soils and both behave similarly in the environment (DOE, 1992c). Preliminary studies (EG&G, 1991b) of the land near RFP have shown that soils in some areas contain plutonium and americium at levels higher than what can be attributed to background levels (defined as world-wide fallout from nuclear testing). These studies have concluded that most of the plutonium in IHSS 199 was deposited by dust blown from the 903 Pad, which was capped with asphalt in 1969 to prevent further wind dispersion from that location (EG&G, 1991b).

The Final Past Remedy Report (DOE, 1991a) concluded that remediation implemented thus far has reduced plutonium concentrations in the soils. The Final Past Remedy Report (DOE, 1991a) also states that according to a conservative preliminary health risk assessment (DOE, 1991b), IHSS 199 does not appear to pose any immediate threat to human health.

Plutonium can be released from surface soils into the air by wind erosion and into surface water by runoff. Plutonium can also be taken up in the food chain by ingestion of plants with surficial PuO_2 contamination, but has not been shown to concentrate or accumulate in biota (DOE, 1991a). Organic and inorganic constituents will not be assessed in IHSS 199 (soils) because none have been observed above background in the OU 3 surface soils. There have been no documented sources of release that would allow dispersion via air to OU 3 according to the OU 3 work plan (DOE, 1992c).

Groundwater is not a viable transport medium for plutonium from IHSS 199 surface soils in the RFP area. Groundwater does not appear to flow offsite. Flow from the unconfined system surfaces before leaving the RFP boundary and discharges to the streams on the RFP of which Woman Creek, Walnut Creek, and Smart Ditch flow into OU 3. Groundwater in the confined (deeper) system does not discharge to the streams. Effective completion of this pathway is not likely because of the interconnection with surface water in OU 3 and the very low horizontal flow velocity (DOE, 1992c). Further, research and investigation of plutonium mobility at other locations have demonstrated that plutonium transport through unsaturated porous media is negligible (Andelman and Rozzell, 1970; Brookins, 1984; Kim et al., 1984; Shade et al., 1984; Silva et al., 1979; and Staley et al., 1979).

Ingestion of homegrown garden vegetables and beef that may be potentially contaminated with radionuclides were identified as pathways of potential concern for IHSS 199. An evaluation of these two pathways for IHSS 199 was conducted by performing a review of the available literature; of data on uptake of plutonium and americium in plants and cattle; of the risk assessment presented in the Final Past Remedy Report (DOE, 1991a); a review of EPA's Transuranic Elements, Volume 1, Elements of Radiation Protection; and a review of Transuranic Elements, Volume 2, Technical Basis for Remedial Actions. Since there is limited use of home gardens and no subsistence beef consumption in the OU 3 study area (based on walkthrough surveys conducted in the area), conclusions were drawn from the information presented in the following paragraphs.

Plutonium and americium particulates that have eroded from surface soils by wind or water have been recognized in the Final Past Remedy Report (DOE, 1991a), and in the OU 3 Workplan (DOE 1992c) to have the potential for being incorporated into the food chain by settling on foliar surfaces or absorbing through the surfaces of plants. However, foliar retention depends on the physical structure of the plant. Surface and foliar contamination can be removed by weather such as rain or wind, by dropping plant parts (field loss), (DOE, 1992c) or by removal of deposition (washing).

Foliar retention of plutonium and americium is highly unlikely because of the absorption characteristics of leaves and roots and the chemical and physical characteristics of these transuranic elements. In order for terrestrial vegetation to absorb and accumulate plutonium and americium, the elements need to be dissolved in water for root uptake. Absorption of nutrients or other chemicals across the leaf surface is not a significant uptake route for terrestrial plants. The foliar surfaces are used strictly for gas exchange, and are impermeable to water or nutrients.

Studies have indicated that the dry deposition of radionuclides on foliar surfaces does not significantly contribute to the concentrations of radionuclides within the plant itself. Once the leaves are washed of any dust, the detected concentrations of radionuclides significantly decreases. Similarly, root uptake of radionuclides appears to be negligible because of the chemical and physical properties of these elements. In order for the chemicals to be absorbed across root surfaces, the elements must be solubilized within the soil pore water. Because of the low solubility of these chemicals, this is an unlikely exposure pathway to the plant.

Investigations have shown a cumulative (root + foliar) uptake rate of 10^{-3} for cultivated crops. In addition, a transfer rate of 10^{-3} across the gastrointestinal tract has been established, for a total transfer potential of 10^{-6}. Based upon these uptake rates, absorption, and therefore exposure, of plutonium and americium through the ingestion of contaminated crops would be negligible.

Plutonium taken up in the food chain by animals will not tend to bioconcentrate or bioaccumulate (EPA, 1990b). The gastrointestinal absorption factor for PuO_2 listed by the International Commission on Radiation Protection (ICRP) is 1×10^{-5}, indicating that plutonium will not be easily absorbed through the intestine, but rather will pass through the intestine and be discharged as waste (ICRP, 1979). In adult animals, less than 0.01 percent of ingested plutonium is absorbed from the intestine (ICRP, 1988).

In Transuranic Elements, Volume 1, Elements of Radiation Protection, EPA states that "in general, the most important pathway for human exposure from plutonium oxide and other transuranium radionuclides in the environment is expected to be inhalation. This route provides a direct pathway for alpha particles to enter a sensitive organ, the pulmonary lung." (DOE, 1980b) This report also states that the gastrointestinal wall (gut wall) acts as a barrier to plutonium absorption in blood. The dose to the gut wall itself is not a major pathway of radiation exposure because plutonium alpha particles have a short finite range in tissue of 41 microns. The radiosensitive dividing cells in the gut wall are more than 100 microns distant from the gut contents and are effectively isolated from the alpha radiation (EPA, 1990a).

The characteristics of plutonium in plants, animals, and humans, and the results of the following evaluations, serve to focus on the inhalation route of exposure as the main pathway of concern with minor consideration given to the direct ingestion of soil in the food chain uptake. Walk-through surveys conducted in OU 3 neighborhoods have documented few home gardens in the OU 3 study area. These observations lead to the conclusion that a limited population would be exposed by the potential pathway of leafy vegetable ingestion.

The Final Past Remedy Report (DOE, 1991a) was prepared in response to the Interagency Agreement (IAG, 1991) and was refined to establish the OU 3 Workplan (DOE, 1992c), which introduced the primary exposure pathways for OU 3. The Final Past Remedy Report contains an exposure pathway analysis and a generic risk assessment for exposure to plutonium contamination in soil. Because the available data were not of the quality required to perform a quantitative risk assessment, the risk assessment contained in the Final Past Remedy Report evaluates the relative differences in risk if plutonium concentrations in soil where the magnitude of 1 pCi/g, 10 p/Ci/g, and 100 pCi/g, and ranks the transport and release mechanisms for current and future land uses for IHSS 199. Major assumptions used to quantitate the generic risks in the Final Past Remedy Report include a resident consuming 33 grams of homegrown leafy vegetables and 89 grams of homegrown root and tuber vegetables per day for 30 years, which totals 122 grams per day. This number represents the reasonable worst-case consumption rate as described in the EPA Exposure

Factors Handbook. The typical consumption rate is 78 grams/day, based on a national survey conducted by the USDA in 1980 (EPA, 1989b). The reasonable worst-case consumption rates were used to assess the generic risks presented in the Final Past Remedy Report; however, risks would have been even lower if typical consumption rates had been used.

Inhalation of dust and ingestion of soil were evaluated in the Final Past Remedy Report's generic risk assessment for the current use setting. The generic risk assessment used a recreational exposure scenario with inhalation of dust contributing the greatest risk–1×10^{-8} for soil concentrations of 1 pCi/g. Inhalation of suspended particulates, direct soil ingestion, and foliar deposition on grazing lands and home gardens were also evaluated in the future residential land use setting for IHSS 199 in this generic risk assessment. For the future residential setting, the ingestion of leafy vegetables contributed the greatest risk, 1.1×10^{-7}, if soil concentrations were 1 pCi/g. The ingestion of tubers, the inhalation of dust, and the ingestion of soil all contributed approximately the same risk to the hypothetical plutonium 239 soil concentrations.

Another radiological assessment for Rocky Flats Plant was presented in the EPA report, Transuranic Elements, Volume 2, Technical Basis for Remedial Actions. (EPA, 1990b). This assessment presented an evaluation of bone dose from the ingestion of foodstuffs and listed estimated committed doses (in the 70th year) to red bone marrow of a critical group near the RFP. As in the Final Past Remedy Report, the highest doses to the bone were attributed to the leafy vegetables, with plutonium contributing 0.071 mrad/year. It should be noted that the total dose attributed by all pathways totaled 0.25 mrad/year (without consideration of pica). When pica was considered, the total dose resulted in 0.65 mrad/year, with soil ingestion as the main contributor to that dose.

Both this assessment and the Final Past Remedy Report attributed the ingestion of cow milk and beef muscle and liver to a less than 0.2 percent contribution of total risk or dose. A study conducted by the EPA National Environmental Research Center, which evaluated actinide concentrations in tissues of cattle grazing near the Rocky Flats Plant in 1973, reported that the level of plutonium 239 found in cattle was similar to those found in the general U.S. population from nuclear fallout (EPA, 1975). This study concluded that the human bone dose accumulated in 50 years of ingestion of the beef results in 0.02 rem, an insignificant fraction of the 8.5 rem background dose accumulated by Denver area residents in that time period (EPA, 1975). Bioconcentration and bioaccumulation of plutonium in beef cattle are considered negligible and therefore will not be further considered in the conceptual model.

In summary, the consumption of residential garden produce and homegrown beef are considered minor pathways, relative to inhalation of dust and ingestion of soil, based on the following considerations:

- The data available in the literature show plutonium and americium uptake by fruits and vegetables is insignificant.
- The food chain effects through bioconcentration and bioaccumulation are negligible.
- There are a limited number of home gardens and there is limited subsistence beef consumption in the OU 3 study area.
- Refinements to the OU 3 Workplan, based on the Final Past Remedy Report, indicate that the primary exposure pathways of potential are inhalation and ingestion of soil.

Based on the foregoing considerations, the inhalation of wind-borne particulate soil is considered the primary pathway for quantitative evaluation with potential soil ingestion as a secondary pathway. Subsequent discussion of surface soils focuses on the two pathways.

4.2.2 Conceptual Model for the Reservoirs and Drainages

Figure 4-3 is a general CSM of IHSSs 200 (Great Western Reservoir), 201 (Standley Lake), and 202 (Mower Reservoir). The most likely complete exposure pathways for IHSSs 200 through 202 are identified based on the Historical Information and Summary and Preliminary Health Risk Assessment (DOE, 1991c) and the Work Plan (DOE, 1992c). They are presented in Figure 4-4, IHSS 200-202 (Reservoirs) Human Health Priority Pathways. The primary exposure pathway appears to be inhalation of dry and exposed reservoir and stream sediments dispersed to air through resuspension. Other likely pathways are the ingestion of sediments and surface water. The remaining pathways of ingestion of and dermal contact with groundwater and biota have a lower potential for exposure to site-related COPCs than the first two pathways (DOE, 1992c). The process used to rank the likelihood of each pathway is presented in detail in the Work Plan and is based on chemical characteristics in the sediments and surface water, the fate and mobility of particulates in air and suspended sediments in surface water, and uptake by biota. Again, the specific toxicity of the COPCs and preliminary estimate of risk are not included in the ranking process. Each pathway in Figure 4-4 is presented in detail in Appendix A of the Work Plan (DOE, 1992c). The following is a brief summary of information originally presented in the Work Plan (DOE, 1992c) about the conceptual model and priority pathways.

Plutonium, americium, and possibly metals are the only site-related COPCs likely to exist in drainage and reservoir sediments. Erosion of streambeds in the vicinity of RFP will cause, over time, full sediment loads to be transported downstream rather than permanently deposited within the drainage. If the sediment load were to reach an impoundment such as a holding pond or reservoir, the sediment will gradually settle to form bottom sediments.

A distinction is made in Figure 4-3 between dry and saturated sediments because the potential exposure pathways differ for dry and saturated sediments. Because the water level in the reservoirs fluctuates widely with varying supply and demand on a seasonal basis, sediments in near-shore and other shallow water areas may be exposed for long enough periods to dry. Great Western

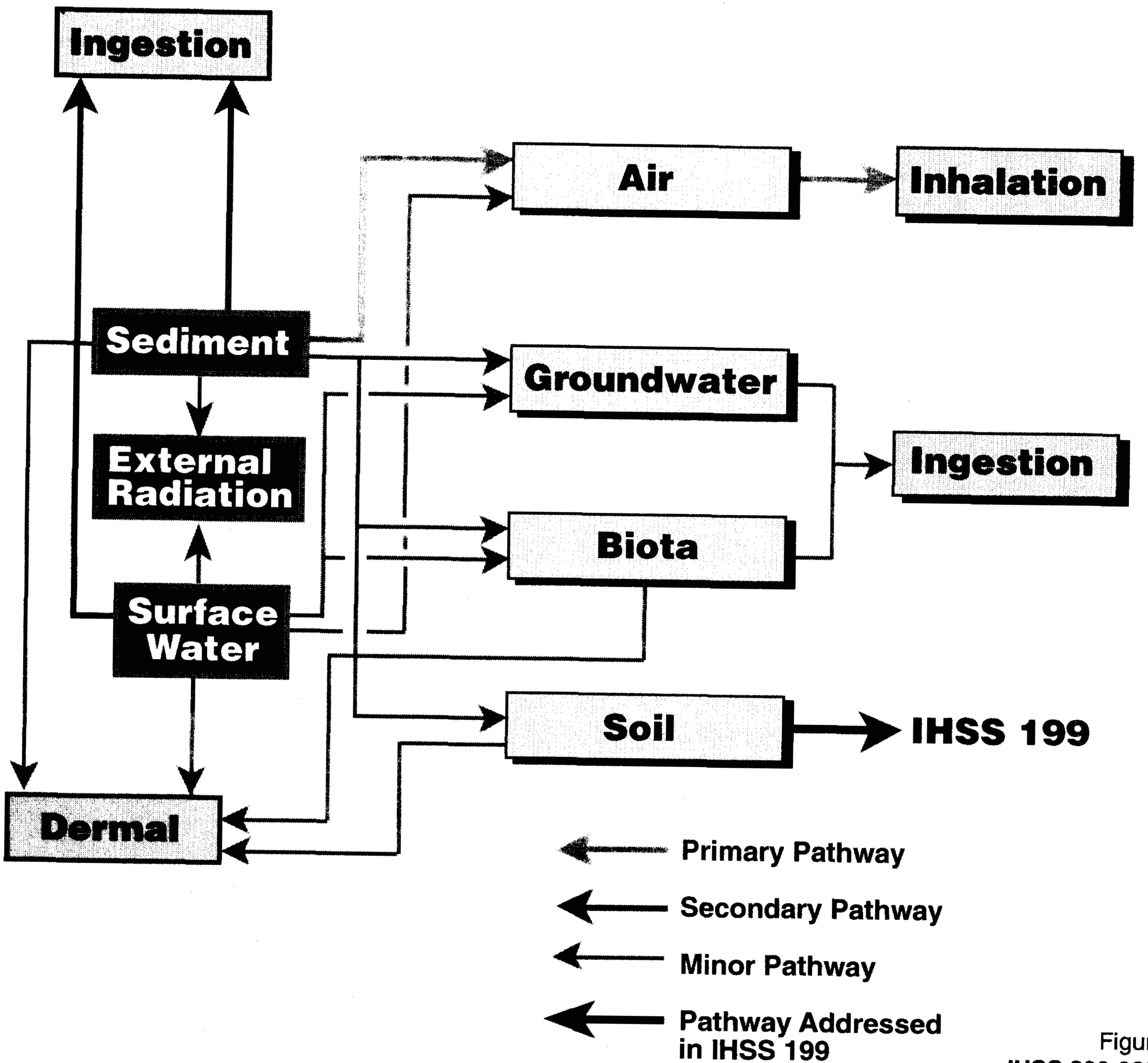

Figure 4-4
IHSS 200-202 (Reservoirs)
Human Health Priority Pathways

DRAWN BY	H. DOUVILLE	CHECKED BY	P. Smith	03/09/93
	03/09/93	CHANGED BY		
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Reservoir may be drained in the future, allowing sediment to be exposed to air. Sediments in the ephemeral drainage may also be dry during dry seasons. Dry sediments are subject to a similar set of release mechanisms as that described for surface soils.

Plutonium can be released from dry, exposed reservoir or stream sediments by wind erosion into the air. Plutonium can also be taken up in the food chain by ingestion of plants with surficial contamination as a result of settled dust eroded from exposed sediments by wind. Plutonium has not been shown to concentrate or accumulate in biota (DOE, 1992c). Based on previous information (DOE, 1991c), this pathway is considered of negligible concern.

Groundwater is not a viable transport medium for plutonium from drainages and reservoirs in the RFP area. Further, the results of past studies of Great Western Reservoir and Standley Lake have shown that the plutonium is immobilized in the bottom sediments and is not being leached downward toward the water table. Soluble contaminants in drainage water may be transported to groundwater if the surface water infiltrates the drainage bed (DOE, 1992c). As discussed in Subsection 4.1.1.1, COPC transport in groundwater is not likely to impact receptors in the OU 3 area.

Ingestion of surface water has been identified in the OU 3 Workplan (DOE, 1992c) as a secondary pathway. The conceptual model considers surface water in both reservoirs and streams. To evaluate the exposure pathways for surface water, the preliminary risk assessments in the Historical Information Summary Report and Preliminary Health Risk Assessment (DOE, 1991c) and the Rocky Flats Plant Site Environmental Report (EG&G, 1991) were reviewed. The results of these assessments are discussed in the following paragraphs.

The risk assessment presented in the Historical Information Summary and Preliminary Health Risk Assessment (DOE, 1991c) evaluated the ingestion of water-soluble plutonium and water-suspended plutonium using hypothetical plutonium sediment concentrations. Both current and future reasonable maximum exposure scenarios were used for the residential and recreational settings. The residential setting assumed that a resident consumed untreated water for 30 years. The results of this evaluation assumed a hypothetical concentration of 0.01 pCi/g of water-soluble plutonium, yielding a risk of 6.8×10^{-9}. When a water-soluble plutonium concentration of 10 pCi/g was assumed, the risk estimate was 6.8×10^{-6}.

As noted in Section 3, both Standley Lake and Great Western Reservoir are currently used as drinking water supplies for several cities. Extensive community water monitoring programs are conducted to analyze public water supplies and tap water from several surrounding communities. The Rocky Flats Plant Site Environmental Report (EG&G, 1991) reports that during 1991, drinking water from Boulder, Broomfield, and Westminster was collected weekly, composited monthly, and analyzed for plutonium, uranium, and americium. Tritium analyses were performed on weekly grab samples. Quarterly tap water samples were collected from the communities of Arvada, Denver, Golden, Lafayette, Louisville, and Thornton, and were analyzed for plutonium, uranium, americium, and tritium (EG&G, 1991). All results were compared to background samples previously collected to determine background levels for plutonium, uranium, americium, and tritium in water at distances ranging from 1 to 60 miles from RFP (EG&G, 1991).

The results of analyses for plutonium, uranium, americium, and tritium in Standley Lake and Great Western Reservoir were less than 14 percent of the DOE Derived Concentration Guide (DCG). Ambient site-specific radionuclide standards have been adopted by the State of Colorado for Standley Lake and Great Western Reservoir (CDH, 1992). For both reservoirs, the plutonium and americium standards are 0.03 pCi/L for each. Plutonium and americium results analyzed for 1991, (representing the latest report) were well below this standard for each radionuclide (EG&G, 1991). The State of Colorado uranium standard for Standley Lake is 3 pCi/L and 4 pCi/L for Great Western Reservoir (CDH, 1992). Results from the 1991 monitoring program for uranium are well below this standard (EG&G, 1991).

The EPA Maximum Contaminant Levels (MCLs) for alpha-emitting particles is 5 pCi/L. Once again, all results of available data for Standley Lake and Great Western Reservoir are below this standard.

The quantitative evaluation of ingestion of surface water from Standley Lake and Great Western Reservoir in the residential scenario is not warranted because current water supplies at these reservoirs meet all established regulatory criteria for radionuclides.

Based on the foregoing considerations, inhalation of reservoir and stream sediments dispersed to air is considered as the primary pathway for evaluation, and ingestion of sediments and surface water as the secondary pathway. Subsequent discussions of the reservoirs and drainages focuses on these pathways.

4.2.3 Conceptual Site Model for Exposure to External Radiation in IHSSs 199-202

Two distinct human hazards are presented by radiation—those of external and internal radiation exposure. External radiation exposure is primarily caused by gamma ray emissions from radioactive decay. Gamma and x-rays are the most penetrating of emitted radiations, and are the primary contributors of radiation doses from external exposures. The radionuclides of plutonium and americium produce x-ray and gamma rays; however, they are weak and form only a small percentage of total radioactive energy emitted. Alpha particles are not sufficiently energetic to penetrate the outer layer of skin and do not contribute significantly to the external dose. External exposure to beta particles primarily imparts a dose to the outer layer skin cells, although high-energy beta radiation can penetrate into the human body.

4.3 GENERAL DESCRIPTION OF EXPOSURE SCENARIOS

This section presents general exposure scenarios based on the land uses previously discussed in Section 3.0 for each IHSS. These scenarios are:

- Residential
- Commercial/Industrial

- Recreational
- Agricultural

The general activity patterns and characteristics for each land use are described in the following subsections. A more detailed description is presented in Subsections 4.4 to 4.7 for each IHSS.

4.3.1 General Residential Scenario

According to the Human Health Evaluation Manual, Supplemental Guidance (EPA, 1991), a residential exposure scenario and assumptions appropriate for the scenario should be used whenever there are or may be occupied residences on or adjacent to a site. Any residential scenario carries with it the expectation of frequent, repeated contact with the associated environmental media. The assumptions in the residential scenario account for daily exposure over the long-term and generally can be expected to result in the highest potential exposures.

4.3.2 General Commercial/Industrial Scenario

In the commercial/industrial scenario, workers may be exposed to site-related COPCs within a commercial area or industrial site. According to EPA, these scenarios may apply to individuals who work in, on, or near a site and have repeated exposure to media containing site-related chemicals (EPA, 1991a). Exposure to site-related COPCs for the commercial/industrial scenario for OU 3 addresses workers who perform construction activities and office workers in a standard office-park setting. Construction activities disturb soil and cause fugitive dust emissions that may be further transported by the wind and therefore could be expected to lead to the highest potential short-term worker exposures. Office workers, on the other hand, could be expected to be exposed over longer periods, albeit to much lower levels in the environment.

4.3.3 General Recreational Scenario

According to EPA, this land use addresses exposure of people who spend a limited amount of time at or near a site while playing, fishing, hunting, hiking, or engaging in other outdoor activities (EPA, 1991a). This includes what is often described as the trespasser or random site visitor scenario. For IHSS 199, activities such as biking, hiking, picnicking in parks and open spaces, and golfing or playing on facilities (such as softball fields) could create conditions where surface soils are suspended in the air. For the reservoir IHSSs, activities such as wading and playing in the related drainages could create conditions of exposure to wet and dry sediments. Activities such as boating, fishing, sailboarding, waterskiing, wading, and picnicking could result in exposure to COPCs. Recreational/open space users could include residents who live within the OU 3 study area or those who visit from outside the study area.

4.3.4 General Agricultural Scenario

The general agricultural scenario assumes that a family living on a farm raises animals for meat and cultivates most of the vegetables and fruit consumed by family members (EPA, 1991a). Farm workers can also be considered in this setting. Agriculture worker exposure would differ from the commercial/industrial scenario because of different daily activities, workday length, and seasonal work habits.

The agricultural scenario involving farm families who raise cattle for subsistence beef consumption does not represent a realistic major exposure pathway for several reasons. Based on currently available data, there are no known subsistence beef farm families in the OU 3 study area. Subsection 4.2.2 discussed why the agricultural scenario will not be quantitatively evaluated.

4.4 EXPOSURE SCENARIOS FOR SOILS (IHSS 199)

4.4.1 Current Residential Exposure Scenario—IHSS 199

Information presented in Subsection 3.1.1.1 shows that there is current residential land use within IHSS 199. Based on the CSMs, current residents who live within or adjacent to IHSS 199 could be exposed to site-related COPCs by the following pathways:

- Inhalation of soil particulates suspended in air by wind erosion, both indoors and outdoors
- Ingestion of soil
- External radiation

Based solely on transport mechanisms, *ingestion of surficial dust* that has settled on leaf surfaces of plants such as garden vegetables was identified as a plausible exposure pathway in the conceptual site model and the Final Past Remedy Report (DOE, 1991a). However, fresh leafy plants are usually washed before eating. Some leafy vegetables, such as spinach, are prepared for consumption through steaming or boiling. These removal processes limit the potential for ingestion of contaminated soil on the leaf surface. Based on the previous discussion in Section 4.2.2, the vegetable ingestion pathway is not seen to be a major contributor to potential exposures relative to inhalation of soil particulates or ingestion of soil (DOE, 1991a). As a result, the residential scenario involving the ingestion of surficial dust that has settled on leafy vegetables will not be quantitatively evaluated.

Dermal contact with soil particulates is another exposure pathway addressed in the conceptual models presented in the Work Plan (DOE 1992c). These chemicals have very low dermal permeability constants, and dermal uptake does not contribute to potential exposures to these chemicals relative to inhalation of soil particulates or ingestion of soil (EPA, 1989a). Therefore, this pathway will not be considered further because radionuclides and inorganic elements are not absorbed through the skin. Exposure to external radiation will be addressed.

4.4.2 Future Residential Exposure Scenario–IHSS 199

Subsection 3.2.1.1 identified areas within the IHSS 199 study area planned for residential use. Future land use is predicated on current local zoning and similar planning documents. However, unanticipated or planned rezoning actions cannot be predicted. The future exposure scenario assumes that residents could be potentially exposed to site-related COPCs by the following pathways:

- Inhalation of soil particulates suspended in air by wind erosion, both indoors and outdoors
- Ingestion of surface soil
- External radiation

4.4.3 Current Commercial/Industrial Exposure Scenario–IHSS 199

Because of current residential and commercial/industrial (construction) development, construction workers who currently work within the IHSS 199 study area are potentially exposed to site-related COPCs through the following complete pathways:

- Inhalation of suspended soil particulates in air
- Ingestion of soil
- External radiation

4.4.4 Future Commercial/Industrial Exposure Scenario–IHSS 199

Subsection 3.2.1.2 identified several areas within IHSS 199 that could be developed in the future. Further development could include both construction of residential and commercial/industrial areas. Construction workers could be potentially exposed to site-related COPCs by the following complete exposure pathways:

- Inhalation of suspended soil particulates in air
- Ingestion of soil
- External radiation

Based on projected commercial/industrial development for areas within IHSS 199, office workers could also be expected to work in the area sometime in the future. Office workers could be potentially exposed to site-related COPCs through inhalation of suspended soil particulates from IHSS 199. In our current society, office workers generally spend the majority of their work day indoors in a climate-controlled setting. In addition, modern office parks are usually landscaped and paved, reducing the potential for resuspension of particulate matter. Furthermore, these considerations also limit, if not eliminate, the potential for soil ingestion. Therefore, the office worker scenario will not be quantitatively evaluated.

4.4.5 Current Recreational Exposure Scenario–IHSS 199

Receptors who use the currently designated open spaces, parks, or other areas identified in Subsection 3.2.1.3 for recreation may be exposed to site-related media and COPCs by the following exposure pathways:

- Inhalation of soil particulates suspended in air by wind erosion and by recreational activities

- Ingestion of soil

- External radiation

4.4.6 Future Recreational Exposure Scenario–IHSS 199

Based on future land use planning discussed in Subsection 3.2.1.3, and activities identified previously in the current recreational/open space scenario, the future exposure scenario assumes that people could be exposed through the following routes:

- Inhalation of soil particulates suspended in air by wind erosion and by recreational activities

- Ingestion of soil

- External radiation

4.4.7 Current Agricultural Exposure Scenario–IHSS 199

Subsection 3.1.1.4 identified some current land uses associated with horse-boarding operations, and cattle grazing within IHSS 199. However, there are no family farms (defined as self-sufficient for meat and vegetable production) within the OU 3 area. Therefore, the current agricultural scenario will not be quantitatively evaluated.

4.4.8 Future Agricultural Exposure Scenario–IHSS 199

Based on land use planning information presented in Subsection 3.2.1.4, it is unlikely that agricultural land use will increase beyond current conditions. For this reason, the future agricultural scenario will not be further evaluated.

4.5 EXPOSURE SCENARIOS FOR GREAT WESTERN RESERVOIR (IHSS 200)

Current and future exposure scenarios for Great Western Reservoir (IHSS 200) are described in the following subsections.

4.5.1 Current Residential Exposure Scenario–IHSS 200

Based on the discussion in Subsection 3.1.2.1, there are currently no residential land uses on or adjacent to Great Western Reservoir. The City of Broomfield routinely monitors the municipal water supply for radionuclides and COPCs. Reservoir surface water currently meets all state and federal drinking water criteria. No unacceptable exposures to COPCs from using Great Western Reservoir water would be expected.

Residential areas have been identified as having access to the drainages (Walnut Creek and Lower Church Ditch) associated with the Great Western Reservoir. For the residential scenario, it is assumed that a house is nearby Walnut Creek or Lower Church Ditch and that its residents are exposed to sediments from these streams. It is assumed that there are dry sediments along the creek banks and that these sediments may be dispersed to air by wind erosion. If these sediments are deposited in yards or in residences as house dust, then this contribution to residential exposure will be added to that through a surface soil (IHSS 199) ingestion of soils exposure pathway to estimate total potential exposure. Residents in these areas could also be exposed through the inhalation of dry reservoir and stream sediments dispersed to air, and external radiation.

4.5.2 Future Residential Exposure Scenario–IHSS 200

Plans to provide the City of Broomfield with an alternate water source and the resulting use of Great Western Reservoir were discussed in Subsection 3.2.2.1. Based on that discussion, it is assumed that there will be no restrictions on future land use at Great Western Reservoir. If the reservoir were to be drained, residential development could potentially occur on the former reservoir bottom.

Increased residential development near the drainages has been projected. Such land use could potentially result in the inhalation of reservoir and stream sediments dispersed to air, the ingestion dry reservoir or stream sediments, and external radiation.

4.5.3 Current Commercial/Industrial Exposure Scenario–IHSS 200

There are currently no commercial/industrial uses of Great Western Reservoir or the surrounding land (IHSS 200). There will be no further evaluation of the current commercial/industrial exposure scenario.

4.5.4 Future Commercial/Industrial Exposure Scenario–IHSS 200

IHSS 200 has been identified with future commercial/industrial uses nearby or adjacent to Walnut Creek, Lower Church Ditch, and the Broomfield Diversion Ditch in Subsection 3.2.2.2. The future exposure scenario assumes that construction of residences, office complexes, and multi-family housing will occur in these adjacent areas. This scenario assumes the same type of construction setting and activities that were described in the surface soil IHSS 199. Future workers could be potentially exposed to site-related sediments originating from either Great Western Reservoir or the drainages by:

- Inhalation of reservoir and stream sediments dispersed to air
- Ingestion of dry reservoir or stream sediments
- External radiation

Figure 4-4 illustrates ingestion of sediments dissolved or suspended in surface water as a minor pathway. However this exposure pathway will not be addressed quantitatively in this scenario or in any of the remaining commercial/industrial scenarios for the other reservoir IHSSs. This is because it is unlikely that construction workers would directly contact surface water as part of their work.

4.5.5 Current Recreational Exposure Scenario—IHSS 200

Subsection 3.1.2.3 stated that public access to recreational activities in Great Western Reservoir is restricted. However, it is possible for trespassers to gain access to portions of the reservoir. As discussed in Section 3.0, the reservoir water meets federal and state water quality criteria. There are currently no known unacceptable exposures to COPCs in the surface water in Great Western Reservoir. If the water level of Great Western Reservoir fluctuates, sediments may become exposed to air and dry out with possible sediment resuspension to air.

The three drainages associated with the Great Western Reservoir IHSS are Walnut Creek, Lower Church Ditch, and the Broomfield Diversion Ditch. Currently, there are residences nearby Walnut Creek and Church Ditch. Children, presumably from these nearby residences, have been observed wading and playing along both of these creeks.

This scenario assumes that receptors could contact sediments from activities such as hiking, dirt bike riding, and general play activities. These receptors are assumed to be children and adolescents only, ages 7 to 18, because children under this age lack the mobility (the ability to ride bicycles and the freedom from parental restriction) to gain access to these areas. Exposures to site-related media would include the following complete exposure pathways:

- Inhalation of reservoir and stream sediments dispersed to air
- Ingestion of reservoir and stream sediments by children
- Ingestion of surface water (streams and reservoirs) by children
- External radiation

4.5.6 Future Recreational Exposure Scenario—IHSS 200

Future potential land uses for Great Western Reservoir were identified in Subsection 4.5.2. Consistent with the residential scenario, the future recreational scenario for Great Wester Reservoir assumes that recreational activities could potentially occur on the former reservoir bottom if Great Western Reservoir were to be drained. Recreational activities could include hiking, biking, picnicking, jogging, and other play activities. Recreational activities along the drainages could be expected to remain unchanged.

The following potential exposure pathways have been identified for the Great Western Reservoir (IHSS 200) recreational scenario:

- Inhalation of dry reservoir and stream sediments dispersed to air
- Ingestion of reservoir and stream sediments by children
- Ingestion of surface water (streams) by children
- External radiation

4.5.7 Current and Future Agricultural Exposure Scenario–IHSS 200

No current or future agricultural land uses were identified for the Great Western Reservoir IHSS 200, or its associated drainages, that represent an exposure pathway in the agricultural scenario.

4.6 EXPOSURE SCENARIOS FOR STANDLEY LAKE (IHSS 201)

4.6.1 Current Residential Exposure Scenario–IHSS 201

Based on the discussion in Subsection 3.1.3.1, there are currently no residential land uses adjacent to Standley Lake. Therefore, there are no potential residential exposures to COPCs from sediments adjacent to Standley Lake. The cities of Northglenn, Thornton, and Westminster each monitor their untreated reservoir effluent at their respective water treatment plants for volatile organic compounds and radionuclides prior to water treatment and subsequent distribution. In addition, CDH samples and analyzes water from the Standley Reservoir Dam each month at six different depths for radioactive and nonradioactive contaminants (CDH, 1989). Based on monitoring conducted to date, and the monitoring results reported by EG&G and discussed in Section 4.2.3. Standley Lake water meets all federal and state drinking water standards.

Sediment studies conducted in the last 10 years have shown that contaminated sediments in Standley Lake have been buried by uncontaminated sediments and that the reservoir's water quality has not been adversely affected. Therefore, Standley Lake's water is considered uncontaminated (EG&G, 1991b).

Residential developments are located in close proximity to the drainages, (Woman Creek and Smart Ditch). Residents in these areas could be potentially exposed to site-related sediments and COPCs originating from Standley Lake and Woman Creek through the inhalation of suspended dry sediments in air, and external radiation. If these sediments are deposited in yards or in residences as house dust, then this contribution to residential exposure will be added to that through a surface soil (IHSS 199) ingestion of soils exposure pathway to estimate total potential exposure.

4.6.2 Future Residential Exposure Scenario—IHSS 201

Future residential land use identified for Standley Lake includes increased residential development for areas directly to the east of Standley Lake, as identified in Subsection 3.2.3.1. The pathway for exposure to site-related COPCs would be the same as the current scenarios; namely, through the inhalation of suspended dry sediments in air, and external radiation.

4.6.3 Current Commercial/Industrial Exposure Scenario—IHSS 201

Currently there is no commercial/industrial land use at Standley Lake or its drainages. Therefore, this scenario will not be evaluated.

4.6.4 Future Commercial/Industrial Exposure Scenario–IHSS 201

Based on Subsection 3.2.3.2, commercial/industrial and mixed-use residential areas have been identified for future development for the Standley Lake drainages, Woman Creek, and Smart Ditch. Consistent with the commercial/industrial scenarios developed for surface soils and Great Western Reservoir, this scenario addresses the potential exposure of a construction worker to sediments that have originated from Standley Lake, Woman Creek, or Smart Ditch. The following pathways have been identified:

- Inhalation of suspended reservoir and stream sediments dispersed to air
- Ingestion of reservoir and stream sediments
- External radiation

4.6.5 Current Recreational Exposure Scenario–IHSS 201

As discussed in Subsection 3.1.3.3, Standley Lake is currently used as a recreational water body, with boating, fishing, sailboarding, water skiing, wading, fishing, and picnicking allowed. There is no swimming allowed at Standley Lake because of its designation as a public water supply. As discussed in the residential scenario (Subsection 4.5.1), Standley Lake currently meets all federal and state drinking water standards. Therefore, surface water ingestion will not be addressed.

This scenario assumes that children have access to Woman Creek and Smart Ditch to engage in wading activities and other play. This scenario further assumes that receptors could contact sediments from activities such as hiking, dirt bike riding, and general play activities. These receptors are assumed to be children and adolescents only, ages 7 to 18, accounting for the restricted mobility of younger children (see Subsection 4.4.5). People engaged in recreational activities in IHSS 201 could potentially be exposed by the following routes:

- Inhalation of suspended reservoir and stream sediments dispersed to air

- Ingestion of reservoir and stream sediments by children
- Ingestion of surface water (streams) by children
- External radiation

Standley Lake is regularly stocked for sport fishing. A June, 1989, survey of sport fish in Standley Lake by CDH and the Colorado Department of Wildlife (CDOW) analyzed fish to determine if they were safe for human consumption. Walleye, channel catfish, smallmouth bass, and rainbow trout were tested for radionuclides, metals, and priority organic pollutants. Radioactive materials, including plutonium 239-240 and cesium-137, were not detected. Low concentrations of several metals, DDT, and malathion were detected, but the source of these contaminants was not determined and none of the chemicals found were unique to RFP. The CDH concluded that "... consumption of a reasonable quantity of fish from Standley Lake does not represent an appreciable health risk to the public ..." (CDH, 1990).

4.6.6 Future Recreational Exposure Scenario—IHSS 201

Increased recreational uses of Standley Lake are planned for the future. This is discussed in more detail in Subsection 3.2.3.3. The exposure pathways identified for the current scenario will also apply for the future scenario for Standley Lake:

- Inhalation of reservoir and stream sediments dispersed to air
- Ingestion of reservoir and stream sediments by children
- Ingestion of surface water (streams) by children
- External radiation

4.6.7 Current and Future Agricultural Exposure Scenarios—IHSS 201

Although Subsections 3.1.3.4 and 3.2.3.4 stated that water from Standley Lake was used for irrigation, there are currently no family farms (defined as self-sufficient for meat and vegetable production) within the Standley Lake IHSS 201, nor are there projected to be increased agricultural uses. Therefore, the current and future agricultural scenarios will not be quantitatively evaluated.

4.7 EXPOSURE SCENARIOS FOR MOWER RESERVOIR (IHSS 202)

The current and future exposure scenarios for the Mower Reservoir (IHSS 202) are described in the following subsections.

4.7.1 Current Residential Exposure Scenario–IHSS 202

There are currently no residences within the Mower reservoir and its drainages. Therefore, no complete exposure pathways have been identified for this scenario.

4.7.2 Future Residential Exposure Scenario–IHSS 202

As identified in Subsection 3.2.4.1, the future use of Mower Reservoir (IHSS 202) is uncertain. Residential development may occur in the future along drainages to the east of the reservoir. It is assumed that residences will be built near the reservoir and its associated drainages. The primary potential exposure pathway for this scenario is the inhalation of reservoir and stream sediments dispersed to air.

4.7.3 Current Commercial/Industrial Exposure Scenario–IHSS 202

There is no commercial/industrial use identified with Mower Reservoir currently, as discussed in Subsection 3.1.4.2.

4.7.4 Future Commercial/Industrial Exposure Scenario–IHSS 202

Subsection 3.2.4.2 identified the Mower Reservoir IHSS 202 as potentially projected for future development of residential areas and commercial/industrial mixed-use areas. Therefore, the future commercial/industrial scenario will be evaluated using the construction worker scenario previously described. The following are the only exposure pathways that will be evaluated:

- Inhalation of reservoir and stream sediments dispersed to air
- Ingestion of reservoir and stream sediments
- External radiation

4.7.5 Current Recreational Exposure Scenario–IHSS 202

As discussed in Subsection 3.1.4.3, there is currently no public access to Mower Reservoir. Therefore, this scenario will not be evaluated quantitatively.

4.7.6 Future Recreational Exposure Scenario–IHSS 202

Future residential development of the Mower Reservoir area would increase recreational opportunities in this area. Residents could have access to the reservoir and Mower Ditch. This scenario assumes that receptors (children aged 7 to 18 years) could contact sediments from activities such as hiking, dirt bike riding, and general play activities. The following potential exposure pathways have been identified for this scenario:

- Inhalation of reservoir and stream sediments dispersed to air
- Ingestion of reservoir and stream sediments by children
- Ingestion of surface water (streams) by children

4.7.7 Current and Future Agricultural Exposure Scenarios–IHSS 202

Subsections 3.1.4.4 and 3.2.4.4 stated that the purpose of the Mower Reservoir was to provide irrigation and water for livestock. Currently there is no agricultural use scenario in this IHSS where a farm family raises animals for its own meat and cultivates most of its fruits and vegetables. The current use scenario will not be evaluated further, based on the land use discussed in Subsection 3.1.4.4. No future agricultural land uses are projected for Mower Reservoir, as discussed in Subsection 3.2.4.4, therefore, the future agricultural scenarios will not be evaluated.

4.8 SUMMARY

Table 4-1 presents a summary of the complete exposure scenarios and exposure pathways that will be assessed quantitatively. The complete scenarios and pathways are derived from the priority pathways developed in the Work Plan (DOE, 1992c).

Table 4-1
SUMMARY OF EXPOSURE SCENARIOS AND PATHWAYS CONSIDERED FOR QUANTITATIVE ASSESSMENT

Scenarios		Exposure Pathway
Soils (IHSS 199)		
Current	Residential	Inhalation of soil particulates suspended in air by wind erosion
		Ingestion of surface soil
		External radiation
	Commercial/ Industrial	Inhalation of suspended soil particulates in air
		Ingestion of soil
		External radiation
	Recreational/Open Space	Inhalation of soil particulates suspended in air by wind erosion and by recreational activities
		Ingestion of soil
		External radiation
Future	Residential	Inhalation of soil particulates suspended in air
		Ingestion of surface soil
		External radiation
	Commercial/ Industrial	Inhalation of suspended soil particulates in air
		Ingestion of soil
		External radiation
	Recreational/Open Space	Inhalation of soil particulates suspended in air by wind erosion and by recreational activities
		Ingestion of soil
		External radiation
Great Western Reservoir (IHSS 200)		
Current	Residential	Inhalation of reservoir and stream sediments dispersed to air
		External radiation

Table 4-1
SUMMARY OF EXPOSURE SCENARIOS AND PATHWAYS CONSIDERED FOR QUANTITATIVE ASSESSMENT
(Continued)

Scenarios		Exposure Pathway
	Recreational/Open Space	Inhalation of reservoir and stream sediments dispersed to air
		Ingestion of reservoir or stream sediments by children
		Ingestion of stream surface water by children
		External radiation
Future	Residential	Inhalation of reservoir and stream sediments dispersed to air
		Ingestion of reservoir or stream sediments
		External radiation
	Commercial/ Industrial	Inhalation of reservoir and stream sediment dispersed to air
		Ingestion of reservoir and stream sediments
		External radiation
	Recreational/Open Space	Inhalation of reservoir and stream sediment dispersed to dispersed air
		Ingestion of reservoir and stream sediments by children
		Ingestion of surface water (streams) by children
		External radiation
Standley Lake (IHSS 201)		
Current	Residential	Inhalation of reservoir and stream sediments to dispersed air
		External radiation
	Recreational/Open Space	Inhalation of reservoir and stream sediments dispersed to air
		Ingestion of reservoir and stream sediments by children
		Ingestion of surface water (streams) by children
		External radiation
Future	Residential	Inhalation of reservoir and stream sediments dispersed to air
		External radiation

Table 4-1
SUMMARY OF EXPOSURE SCENARIOS AND PATHWAYS CONSIDERED FOR QUANTITATIVE ASSESSMENT
(Concluded)

Scenarios		Exposure Pathway
	Commercial/ Industrial	Inhalation of reservoir and stream sediments dispersed to air
		Ingestion of reservoir and stream sediments
		External radiation
	Recreational/Open Space	Inhalation of reservoir and stream sediments dispersed to air
		Ingestion of reservoir and stream sediments by children
		Ingestion of surface water (streams) by children
		External radiation
Mower Reservoir (IHSS 202)		
Future	Residential	Inhalation of reservoir and stream sediments dispersed to air
		External radiation
	Commercial/ Industrial	Inhalation of reservoir and stream sediments dispersed to air
		Ingestion of stream sediments
		External radiation
	Recreational/Open Space	Inhalation of reservoir and stream sediments dispersed to air
		Ingestion of reservoir and stream sediments by children
		Ingestion of surface water by children
		External radiation

Section 5
EXPOSURE MODELS

5.0 EXPOSURE MODELS

Exposure is quantified by estimating chemical intake based on medium-specific exposure point concentrations. Parameters that affect the intake estimates include:

- Rate of media contact or intake
- Frequency of contact
- Duration of contact
- Body weight of the exposed individual

This section presents the methodology and model parameters used to estimate medium-specific intakes for chemical and radionuclides of potential concern (COPCs), based on the potentially complete exposure pathways described in Section 4.0 of this TM. Actual estimates of intake are not presented in this memorandum. The chemical intake data are contingent upon current site characterization studies to provide estimated exposure point concentrations that will be implemented at a later date in developing exposure estimation and risk characterization.

5.1 ESTIMATING EXPOSURE

5.1.1 Non-Radiological COPCs

Average daily intakes (ADI) are estimated using contact rates that represent "average" values (for example, some measure of central tendency over time). These intakes are expressed as mass of chemical per kilogram of body weight per day (e.g., milligrams [mg]/kg-day). Six basic parameters are used to estimate intake:

- Intake rate
- Exposure frequency
- Exposure duration
- Body weight
- Averaging time
- Medium-specific chemical concentrations

Intake through ingestion or inhalation can be described by the following equation:

$$ADI = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

where:

ADI = average daily intake of a given contaminant (mg/kg-day)
C = medium-specific concentration of a given contaminant
IR = contact rate of medium (for example, L water/day, kg soil/day, or m^3 air/day)
EF = exposure frequency (number of days of exposure per year)
ED = exposure duration (number of years of exposure)
BW = average body weight over the exposure period (kg)
AT = averaging time is the period over which exposure is averaged (days)

5.1.2 Radiological COPCs or Constituents

Ingestion or inhalation of radionuclides and their subsequent deposition in receptor tissues or organs will result in a radiation dose to those systems as well as surrounding systems. This intake is a function of the radionuclide activity and the frequency and duration of exposure to the radionuclide. Calculation of intake rates for radionuclides are made in the same manner as nonradiological chemicals except neither averaging time nor body weight are used. The resulting calculation is an estimate of radionuclide intake, expressed in units of radioactivity (such as Curie or becquerel), which are defined below:

- Curie (Ci) = the traditional unit of measurement of radioactivity based on the rate of radioactive disintegration. One Curie is defined as 3.7×10^{10} (37 billion) disintegrations per second.

- Becquerel (Bq) = one radioactive disintegration per second (EG&G, 1990b).

The intake formula is modified to estimate intake as follows:

$$I = C \times IR \times EF \times ED$$

where:

I = activity intake (for example, pCi)

C = radionuclide concentration (for example, pCi/g or pCi/m^3)

IR = intake rate; amount of media taken into the body per unit time (for example, /g/day or m^3/day)

EF = exposure frequency (number of days of exposure per year)

ED = exposure duration (number of years of exposure)

The radiation dose is a function of the type of radiation emitted by the radionuclide. The dose equivalent was developed to normalize the unequal biological effects from the different types of radiation. Because radiation doses from systemically incorporated radionuclides may continue long after the intake of the nuclide has ceased, doses to specific tissues and organs from internal radionuclides are typically reported in terms of the committed dose equivalent. The committed dose equivalent to specific organs as a result of intake of the radioactive material is estimated by multiplying the intake of each radionuclide by the appropriate dose conversion factor (DCF). The committed dose equivalents for each radionuclide are then summed to obtain a total committed dose equivalent.

5.2 INTAKE ASSUMPTIONS

This section describes the variables used to estimate intake. Intake assumptions are developed for each exposure route identified in TM 2 based on the medium under consideration and assumed population activity patterns. EPA has recommended the use of the reasonable maximum exposure (RME) to express the upper bound of potential exposures that could reasonably occur in an area. Chemical-specific exposures are estimated for individual pathways. If the RME scenario includes more than one pathway, the exposures are summed across pathways (EPA, 1989).

EPA (1989) suggests that specific values for each parameter in the exposure equation be combined to generate the RME. The upper 95th percentile upper confidence limit of the arithmetic mean for the sampling data is recommended for intake equations, although other approaches (such as basing the confidence limit calculation on the median) may be more appropriate based on the distribution of the data set.

In some instances, the measures of data tendency are used. As an example of an RME duration, EPA uses 30 years at one residence to represent the upper 90th percentile for exposure duration at one residential location. Body weights represent the arithmetic average body weight over the exposure period. Furthermore, site-specific values may be used if adequate supporting documentation exists.

Based on recent EPA guidance (EPA, 1992), intake estimation should also consider the "typical" or central tendency exposure. As noted above, the RME represents an upper bound situation described by the 90th or 95th percentile upper confidence limit of the actual distribution. In contrast, the typical exposure is described by approximating the 50th percentile, or median, of the actual distribution.

Typical exposures estimates use 50th percentile values for the various exposure factors. Exposure parameters are modified based on site- or regional-specific information to derive estimates to represent the typical exposure. These include, but may not be limited to, the following:

- Numbers of days children might be expected to play outdoors based on school schedules and weather conditions

- Numbers of days recreationists might be expected to visit open space and park areas in the OU 3 area based on weather conditions

- Numbers of days when precipitation (greater than 0.01 inch) would be expected to suppress dust, number of days of snowcover, or days of frozen soil

The exposure assumptions and intakes presented in Tables 4-1 through 4-8 are based on RME exposure conditions.

Table 5-1
EXPOSURE ASSUMPTIONS[1]
FOR INHALATION OF SOIL PARTICULATES (IHSS 199) AND SEDIMENT PARTICULATES (IHSS 200 to 202)
DURING RESIDENTIAL LAND USE

Parameter	RME Adult	RME Child
Inhalation rate (m^3/hr)[2]	0.83	0.70
Exposure time (hours/day)[3]	24	24
Exposure frequency (days/year)[4]	350	350
Exposure duration (years)[4]	24	6
Deposition factor[5]	0.25	0.25
Body weight (kg)[6]	70	15
Averaging time (years)[3,6]		
Noncarcinogenic	24	6
Carcinogenic	70	70

[1]These assumptions will be used to estimate media intake for the following residential exposure scenarios: current and future land use at IHSSs 199, 200, and 201; and future land use at IHSS 202.
[2]This is equivalent to 20 m^3/day (EPA, 1991a). The child's inhalation rate is equivalent to 16.8 m^3/day and was calculated using data provided in EPA Exposure Factors Handbook, (EPA, 1989a).
[3]This RME exposure time assumes that 24 hours per day is spent at home (EPA, 1991a).
[4]EPA, 1991a.
[5]Twenty-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed within lung tissue (EPA, 1985).
[6]This parameter is not included in the estimation of media intake for radionuclides.

Table 5-2
EXPOSURE ASSUMPTIONS[1]
FOR INGESTION OF SOIL (IHSS 199) AND SEDIMENTS (IHSS 200)
DURING RESIDENTIAL LAND USE

Parameter	RME Adult	RME Child
Ingestion rate (mg/day)[2]	100	200
Fraction ingested from contaminated source[3]	1	1
Matrix effect[4]	chemical-specific	
Exposure frequency (days/year)[2]	350	350
Exposure duration (years)[2,5]	24	6
Conversion factor (kg/mg)	10^{-6}	10^{-6}
Body weight (kg)[6]	70	15
Averaging time (years)[6]		
Noncarcinogenic	24	6
Carcinogenic	70	70

[1]These assumptions will be used to estimate media intake for the following residential exposure scenarios: current and future land use at IHSS 199, and future land use at IHSS 200.
[2]EPA-recommended value (EPA, 1991a).
[3]The RME fraction ingestion (FI) assumes that residents are always (100 percent of the time) in contact with OU 3 contaminated soils.
[4]The matrix effect describes the reduced availability from the adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. These values are chemical-specific.
[5]The 30-year residential exposure to soil is divided into two calculations. First, a 6-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg). Second, a 24-year exposure duration is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) and an adult body weight (70 kg). These two periods are then time-averaged (EPA, 1991a).
[6]This parameter is not included in the estimation of media intake for radionuclides.

Table 5-3
CONSTRUCTION WORKER EXPOSURE ASSUMPTIONS[1]
FOR INGESTION OF SOIL (IHSS 199) AND SEDIMENTS (IHSS 200)
DURING COMMERCIAL/INDUSTRIAL LAND USE

Parameter	RME
Ingestion rate (mg/day)[2]	50
Fraction ingested from contaminated source[3]	1
Matrix effect[4]	chemical-specific
Exposure frequency (days/year)[2]	250
Exposure duration (years)[5]	1
Conversion factor (kg/mg)	10^{-6}
Body weight (kg)[2,6]	70
Averaging time (years)[2,6]	
Noncarcinogenic	25
Carcinogenic	70

[1]These assumptions will be used to estimate media intake for the following commercial/industrial exposure scenarios: current and future land use at IHSS 199, and future land use at IHSS 200.
[2]EPA-recommended value (EPA, 1991a).
[3]The RME fraction ingestion (FI) assumes that construction workers are in contact with OU 3 contaminated soils 100 percent of their time at work.
[4]The matrix effect describes the reduced availability from the adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. These values are chemical-specific.
[5]This exposure duration assumes that a construction worker may work in the OU 3 area for as long as 1 year. This value is based on professional judgement.
[6]This parameter is not included in the estimation of media intake for radionuclides.

Table 5-4
CONSTRUCTION WORKER EXPOSURE ASSUMPTIONS[1] FOR INHALATION OF SOIL PARTICULATES (IHSS 199) AND SEDIMENT PARTICULATES (IHSSs 200 to 202) DURING COMMERCIAL/INDUSTRIAL LAND USE

Parameter	RME
Inhalation rate (m^3/hr)[2]	1.25
Exposure time (hours/day)[3]	8
Exposure frequency (days/year)[4]	250
Exposure duration (years)[5]	1
Deposition factor[6]	0.25
Body weight (kg)[4,7]	70
Averaging time (years)[4,7]	
Noncarcinogenic	25
Carcinogenic	70

[1]These assumptions will be used to estimate media intake for the following commercial/industrial exposure scenarios: current and future land use of IHSS 199, and future land use at IHSSs 200, 201, and 202.
[2]This is equivalent to 30 m^3/day (EPA, 1991a).
[3]This RME exposure time assumes that 10 hours per day is spent at work and is based on professional judgment.
[4]EPA, 1991a.
[5]This exposure duration assumes that a construction worker may work in the OU 3 area for as long as 1 year. This is based on professional judgment.
[6]Twenty-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed in the lung tissue (EPA, 1985).
[7]This parameter is not included in the estimation of media intake for radionuclides.

Table 5-5
EXPOSURE ASSUMPTIONS[1]
FOR INGESTION OF SOIL (IHSS 199)
DURING RECREATIONAL/OPEN SPACE LAND USE

Parameter	RME Adult	RME Child
Soil ingestion rate from hiking and biking (mg/event)[2]	25/event	50/event
Fraction ingested from contaminated source[3]	1	1
Matrix effect[4]	chemical-specific	
Exposure frequency (events/year)[2]	40	40
Exposure duration (years)[5]	18	12
Conversion factor (kg/mg)	10^{-6}	10^{-6}
Body weight (kg)[6,7]	70	15
Averaging time (years)[6,7]		
Noncarcinogenic	24	12
Carcinogenic	70	70

[1]These assumptions will be used to estimate media intake for recreational exposure scenarios during current and future land use at IHSSs 199.
[2]The ingestion rate is based on 3-hour events with 40 events per year. The 40 events per year consist of recreational/open space use of the OU 3 area twice a week from May through September. This information is based on professional judgment.
[3]The RME fraction ingestion (FI) assumes that recreational users are in contact with contaminated OU 3 soils 100 percent of their time while recreating.
[4]The matrix effect describes the reduced availability from the adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. These values are chemical-specific.
[5]The receptors are assumed for an adult exposed for 18 years and children and adolescents (ages 7 to 18) exposed for 12 years.
[6]EPA, 1991a.
[7]This parameter is not included in the estimation of media intake for radionuclides.

Table 5-6
EXPOSURE ASSUMPTIONS[1]
FOR INGESTION OF SEDIMENTS (IHSSs 200 to 202)
DURING RECREATIONAL/OPEN SPACE LAND USE

Parameter	RME Child
Sediment ingestion rate while playing in streams (children only)[2] (mg/day)	250
Fraction ingested from contaminated source[3]	1
Matrix effect[4]	
Exposure frequency (events/year)[2]	40
Exposure duration (years)[5]	12
Conversion factor (kg/mg)	10^{-6}
Body weight (kg)[6,7]	15
Averaging time (years)[6,7]	
Noncarcinogenic	12
Carcinogenic	70

[1]These assumptions will be used to estimate media intake for the following recreational/open space exposure scenarios: current and future land use at IHSSs 200 and 201, and future land use at IHSS 202.
[2]The EPA-recommended value is 250 mg/day (EPA 1989b). The 40 events per year consist of recreational/open space use of the OU 3 area twice a week from May through September. This information is based on professional judgment.
[3]The RME (FI) assumes that recreational/open space users are in contact with contaminated OU 3 soils 100 percent of their time while recreating.
[4]The matrix effect describes the reduced availability from the adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. These values are chemical-specific.
[5]The receptors are assumed to be children and adolescents ages 7 to 18 exposed for all 12 years.
[6]EPA, 1991a.
[7]This parameter is not included in the estimation of media intake for radionuclides.

Table 5-7
EXPOSURE ASSUMPTIONS[1]
DURING RECREATIONAL/OPEN SPACE LAND USE FOR
INGESTION OF SURFACE WATER FROM STREAMS (IHSSs 200 to 202)

Parameter	RME Child
Surface water ingestion rate (ml/hr)[2]	50
Exposure frequency (events/year)[3]	40
Exposure duration (years)[4]	12
Body weight (kg)[5,6]	15
Averaging time (years)[5,6]	
Noncarcinogenic	12
Carcinogenic	70

[1]These assumptions will be used to estimate media intake for the following recreational/open space exposure scenarios: current and future land use at IHSSs 200 and 201, and future land use at IHSS 202.
[2]The EPA's 1989 recommended value is 50 ml/hr (EPA, 1989b).
[3]The exposure frequency is based on 3-hour events with 40 events per year. The 40 events per year consist of recreational/open space use of the OU 3 area twice a week from May through September. This information is based on professional judgement.
[4]The receptors are assumed to be children and adolescents ages 7 to 18 exposed for 12 years.
[5]EPA-recommended value (EPA, 1991a).
[6]This parameter is not included in the estimation of media intake for radionuclides.

Table 5-8
EXPOSURE ASSUMPTIONS[1]
FOR INHALATION OF SOIL PARTICULATES (IHSS 199) AND SEDIMENT PARTICULATES (IHSSs 200 to 202) DURING RECREATIONAL/OPEN SPACE LAND USE

Parameter	RME Adult	RME Child
Inhalation rate (m^3/hr)[2]	1.25	.70
Exposure time (hours/event)[3]	3	3
Exposure frequency (events/year)[3]	40	40
Exposure duration (years)[4]	24	6
Deposition factor[5]	0.25	0.25
Body weight (kg)[4]	70	15
Averaging time (years)[4]		
Noncarcinogenic	24	6
Carcinogenic	70	70

[1]These assumptions will be used to estimate media intake for the following recreational/open space exposure scenarios: current and future land use for IHSSs 199, 200, and 201; and future land use for IHSS 202.
[2]This is equivalent to 30 m^3/day (EPA, 1991a). The child's inhalation rate is equivalent to 16.8 m^3/day and was calculated using data provided in EPA's Exposure Factors Handbook, 1989 (EPA, 1989b).
[3]This value is based on 3-hour events with 40 events per year. The 40 events per year consist of recreational/open space use of the OU 3 area twice a week from May through September. This information is based on professional judgment.
[4]EPA, 1991a.
[5]Twenty-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed in lung tissues (EPA, 1985).
[6]This parameter is not included in the estimation of media intake for radionuclides.

Section 6
REFERENCES

6.0 REFERENCES

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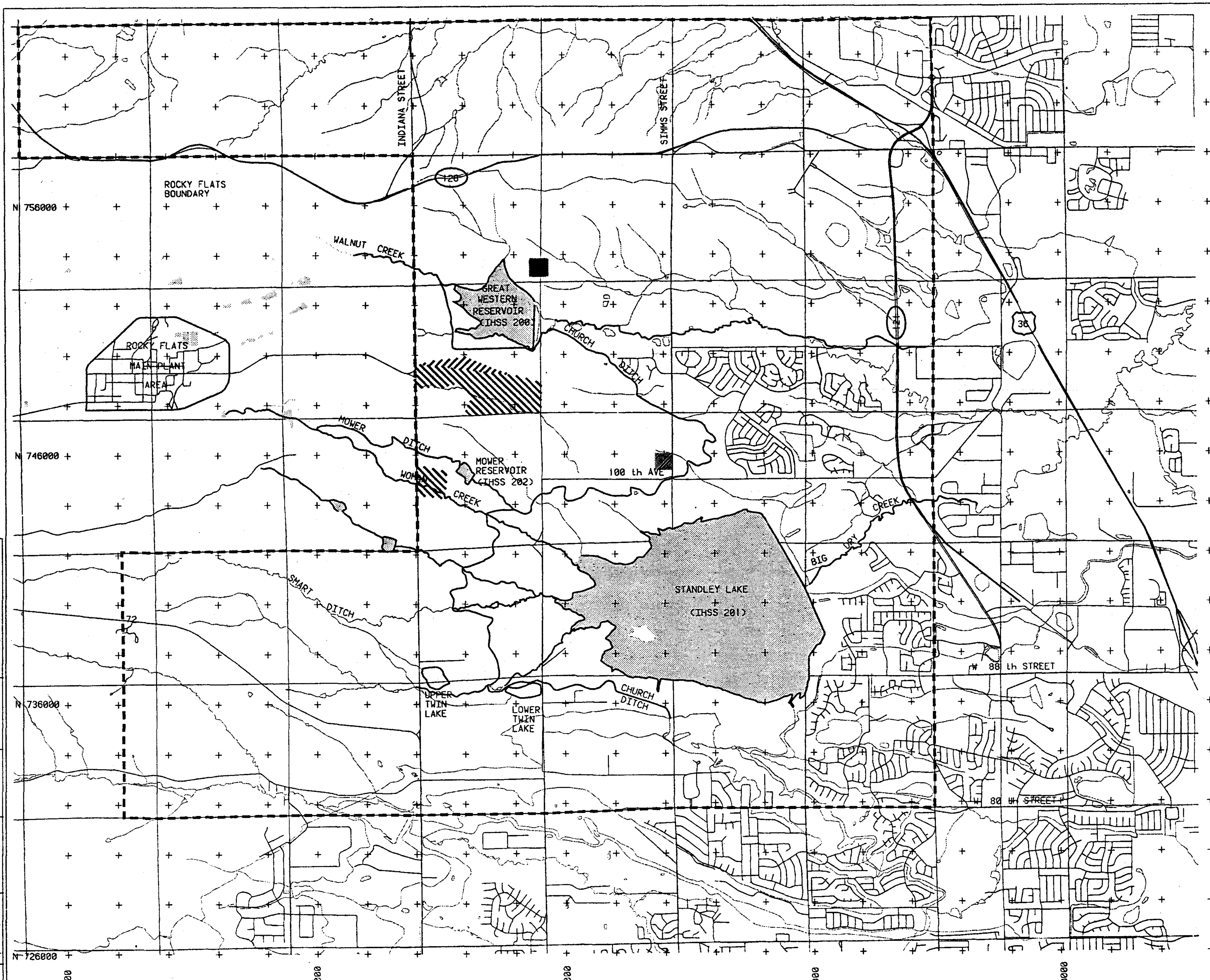


LEGEND

City of Broomfield Remedy Acreage (IHSS 199)

Jefferson County Remedy Acreage (IHSS 199)

OU 3 Study Area

NOTE: THE OU 3 STUDY AREA SHOWN IS NOT INTENDED TO REPRESENT A DEFINED BOUNDARY AND, IN FACT, MAY CHANGE (SEE SECTION 2.2).

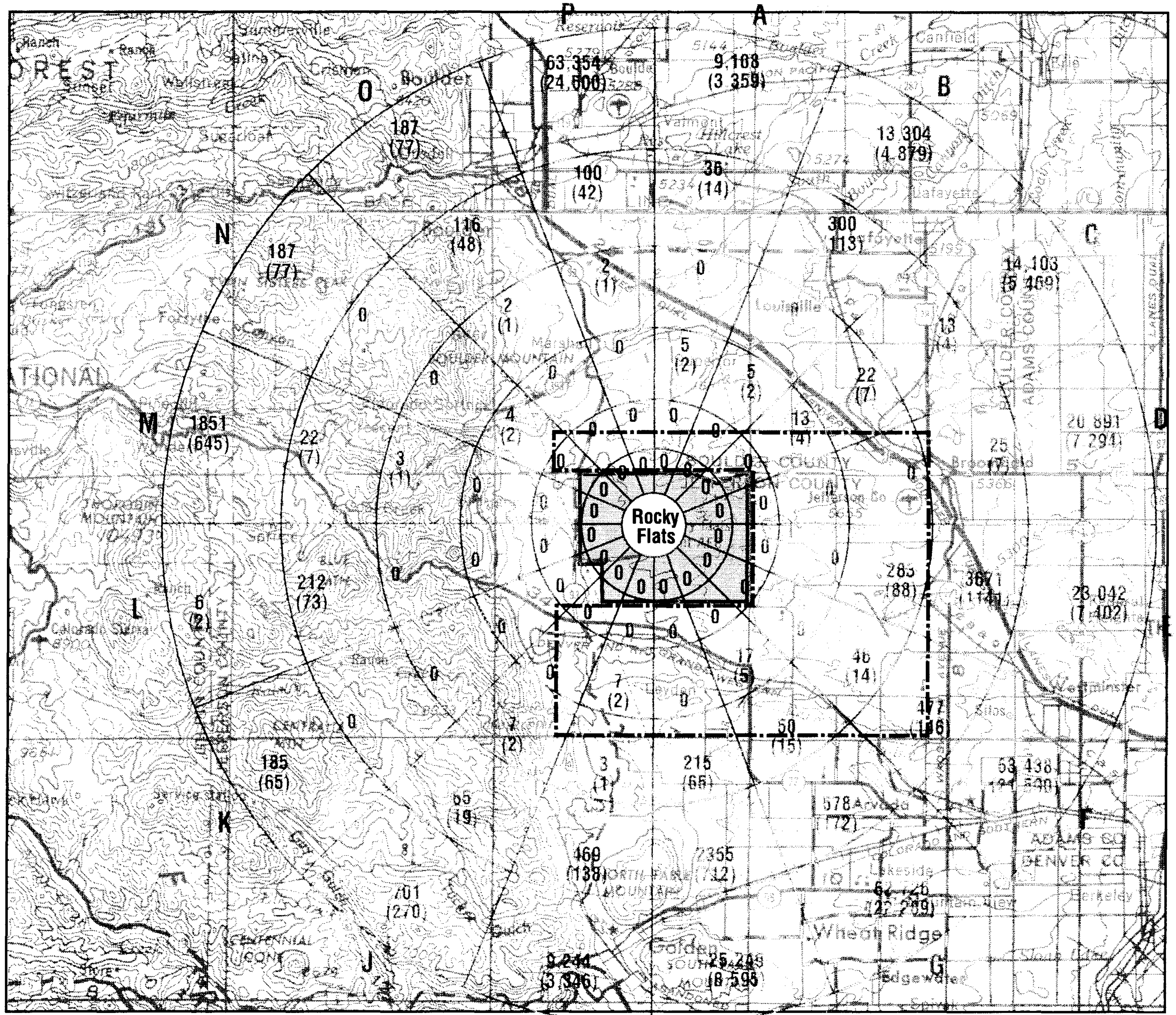
0 2000 4000 6000
GRAPHIC SCALE IN FEET

Figure 2-2
OPERABLE UNIT 3
LOCATION MAP

OPERABLE UNIT 3 ROCKY FLATS PLANT

Base Mapping Sources:
EG&G & Jefferson County

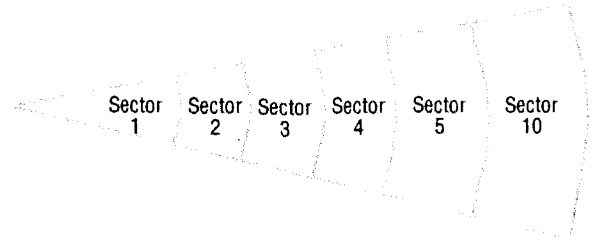
DRAWN BY	M. BROCK 04/16/93	CHECKED BY APPROVED BY	Draft 4/23 P. Smith	DRAWING NUMBER	RFP 1105A



The center of the pie chart is the location of the Rocky Flats Plant.
The numbers in parentheses represent the numbers of households.

— Rocky Flats Plant
-·- OU 3 Boundary

Miles	Sector Name
0-1	Sector 1
1-2	Sector 2
2-3	Sector 3
3-4	Sector 4
4-5	Sector 5
5-10	Sector 10



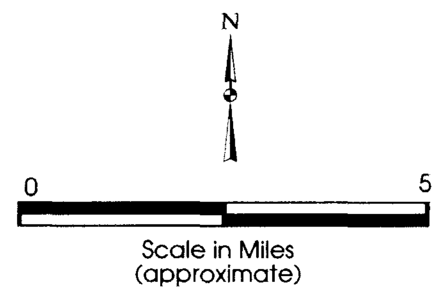
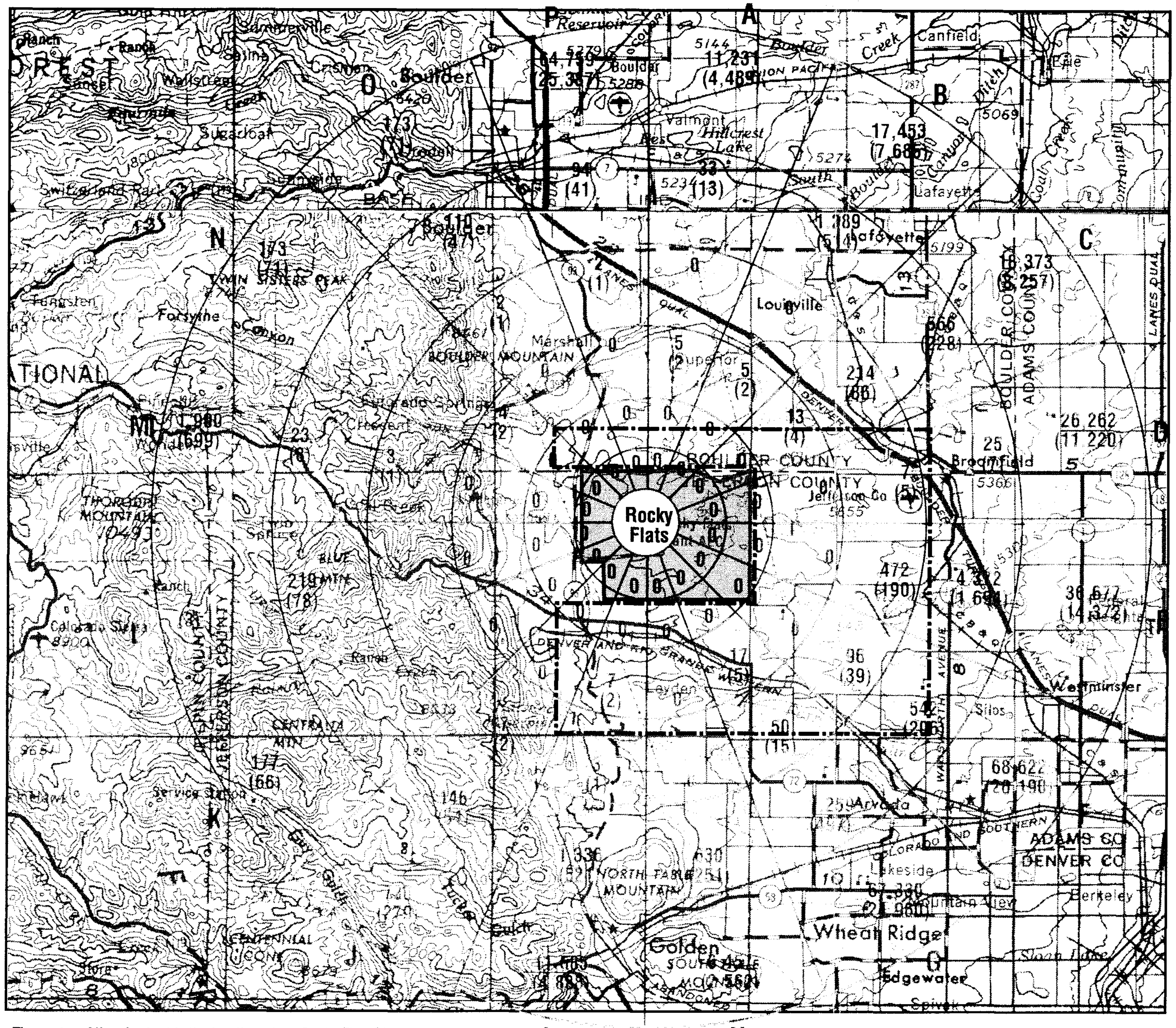


Figure 3-1
1989 POPULATION IN THE VICINITY OF THE ROCKY FLATS PLANT SECTORS 1-5, 10
Source: DOE, 1990

DRAWN BY	M. BROCK 04/16/93	CHECKED BY		DRAWING NUMBER	RFP 1106A
		APPROVED BY			

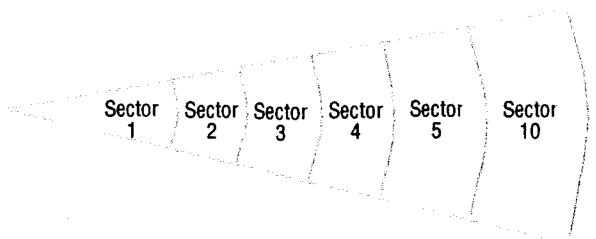


The center of the pie chart is the location of the Rocky Flats Plant.

—— Rocky Flats Plant

—·— OU 3 Boundary

Miles	Sector Name
0-1	Sector 1
1-2	Sector 2
2-3	Sector 3
3-4	Sector 4
4-5	Sector 5
5-10	Sector 10



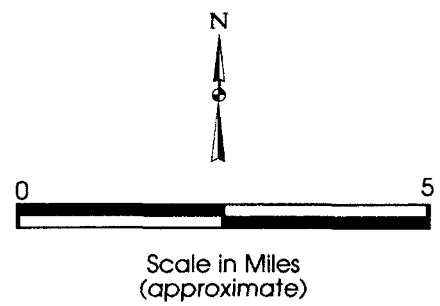
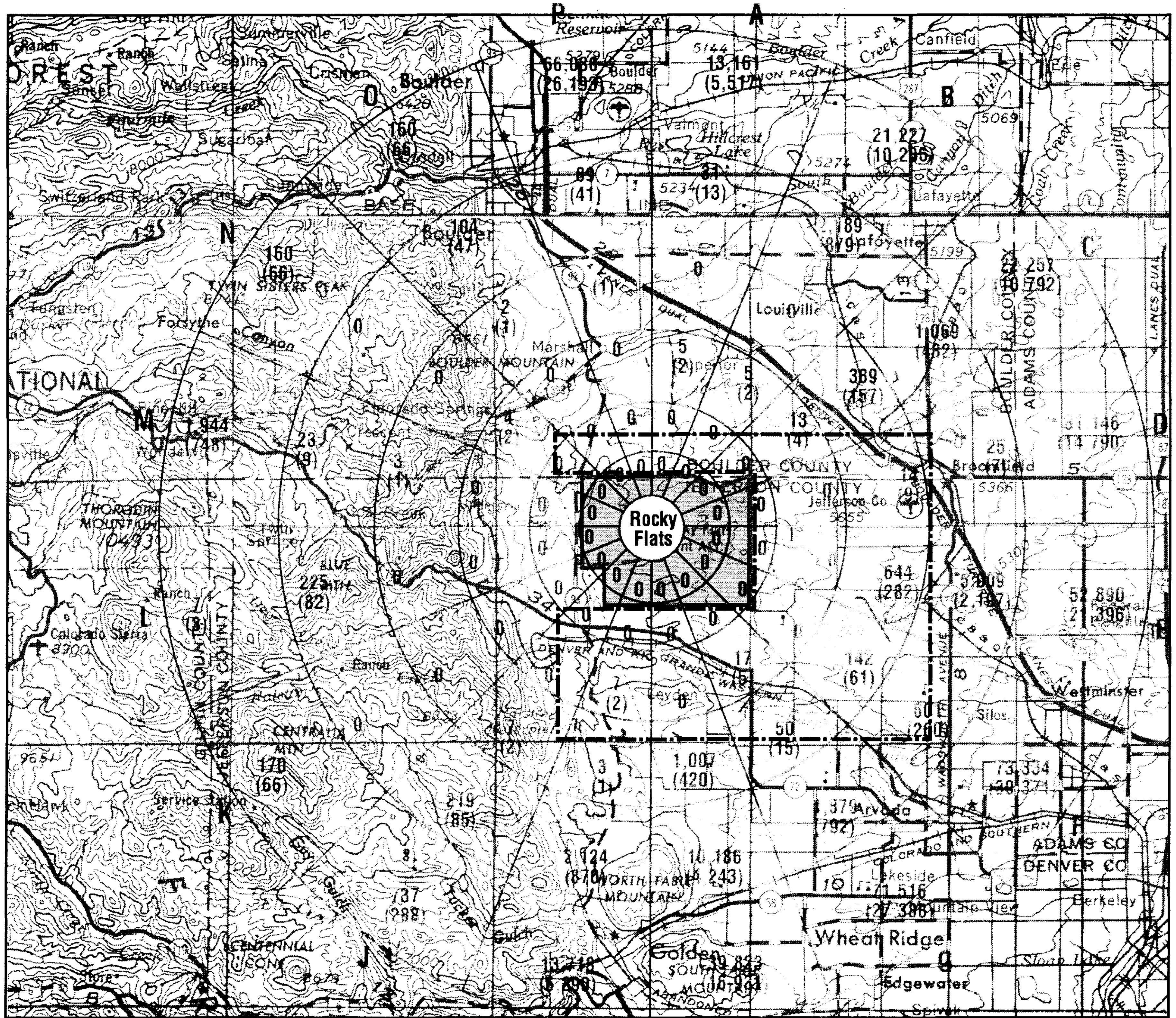


Figure 3-2
2000 POPULATION IN THE VICINITY OF THE ROCKY FLATS PLANT SECTORS 1-5, 10
Source: DOE, 1990

Draft 4/23

DRAWN BY	M. BROCK 04/16/93	CHECKED BY	P Smith		DRAWING NUMBER	RFP 1107A
		APPROVED BY				



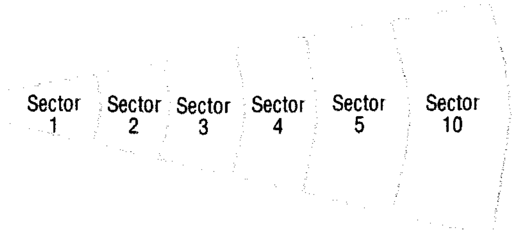
The center of the pie chart is the location of the Rocky Flats Plant.

The numbers in parentheses represent the number of households.

Rocky Flats Plant

OU 3 Boundary

Miles	Sector Name
0-1	Sector 1
1-2	Sector 2
2-3	Sector 3
3-4	Sector 4
4-5	Sector 5
5-10	Sector 10



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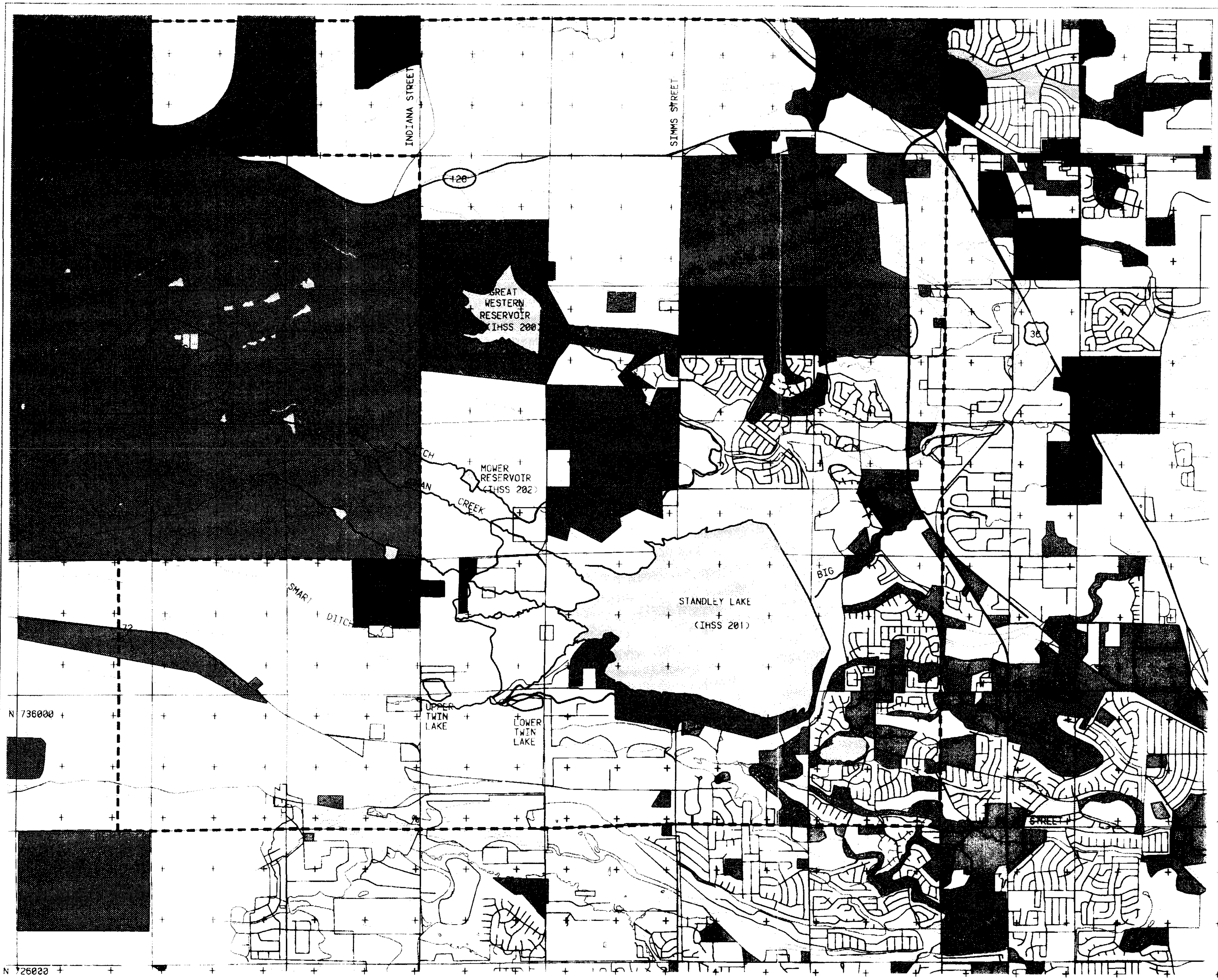
0 5

Scale in Miles (approximate)

Figure 3-3
2010 POPULATIONS AND (HOUSEHOLDS)
SECTORS 1-5, 10
Source: DOE, 1990

DRAWN BY	M. CAMPBELL	CHECKED BY		DRAWING NUMBER	RF0104
	April 23, 1993	APPROVED BY			



LEGEND

- Industrial
- Commercial
- Residential
- Multi-Family Residential
- Water
- Institutional
- Parks/Open Space
- Agricultural
- Unclassified
- Commer/Indust Mix
- Commer/Indust/Resid Mix
- OU 3 Study Area

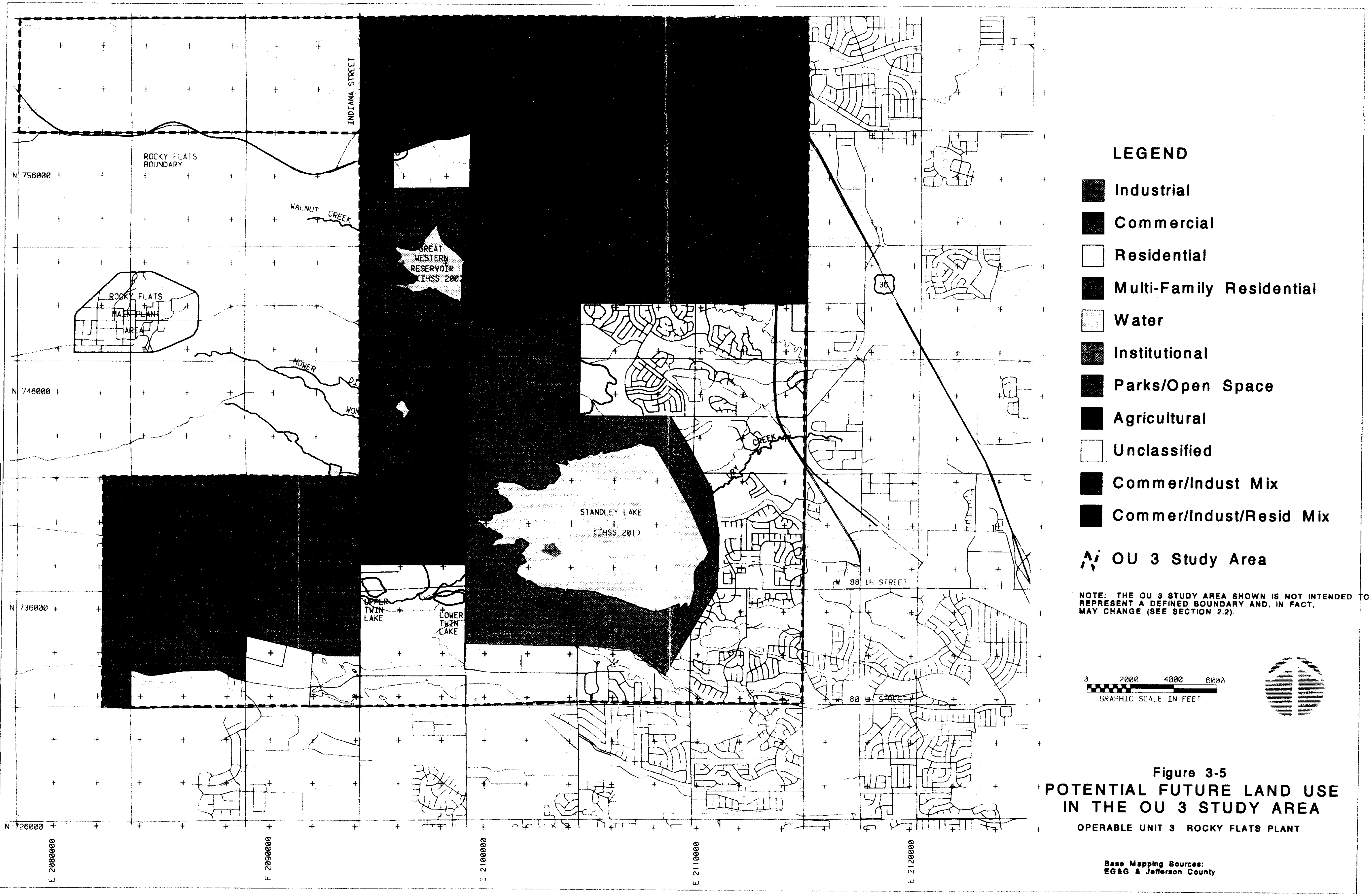
NOTE: THE OU 3 STUDY AREA SHOWN IS NOT INTENDED TO REPRESENT A DEFINED BOUNDARY AND, IN FACT, MAY CHANGE (SEE SECTION 2.2).

0 2000 4000 6000
GRAPHIC SCALE IN FEET

Figure 3-4
CURRENT LAND USE IN THE OU 3 STUDY AREA
OPERABLE UNIT 3 ROCKY FLATS PLANT

Base Mapping Sources:
EG&G & Jefferson County

DRAWN BY	M. CAMPBELL April 23, 1993	CHECKED BY		DRAWING NUMBER	RF0103
		APPROVED BY			



NOTE: THE OU 3 STUDY AREA SHOWN IS NOT INTENDED TO REPRESENT A DEFINED BOUNDARY AND, IN FACT, MAY CHANGE (SEE SECTION 2.2).

Figure 3-5
POTENTIAL FUTURE LAND USE IN THE OU 3 STUDY AREA
OPERABLE UNIT 3 ROCKY FLATS PLANT

Base Mapping Sources:
EG&G & Jefferson County

DRAWN BY	Douville 03/09/93	CHECKED BY	P. Smith 4-23-93	DRAWING NUMBER	RF1060A
		APPROVED BY	J. Nitchals 4-23-93		

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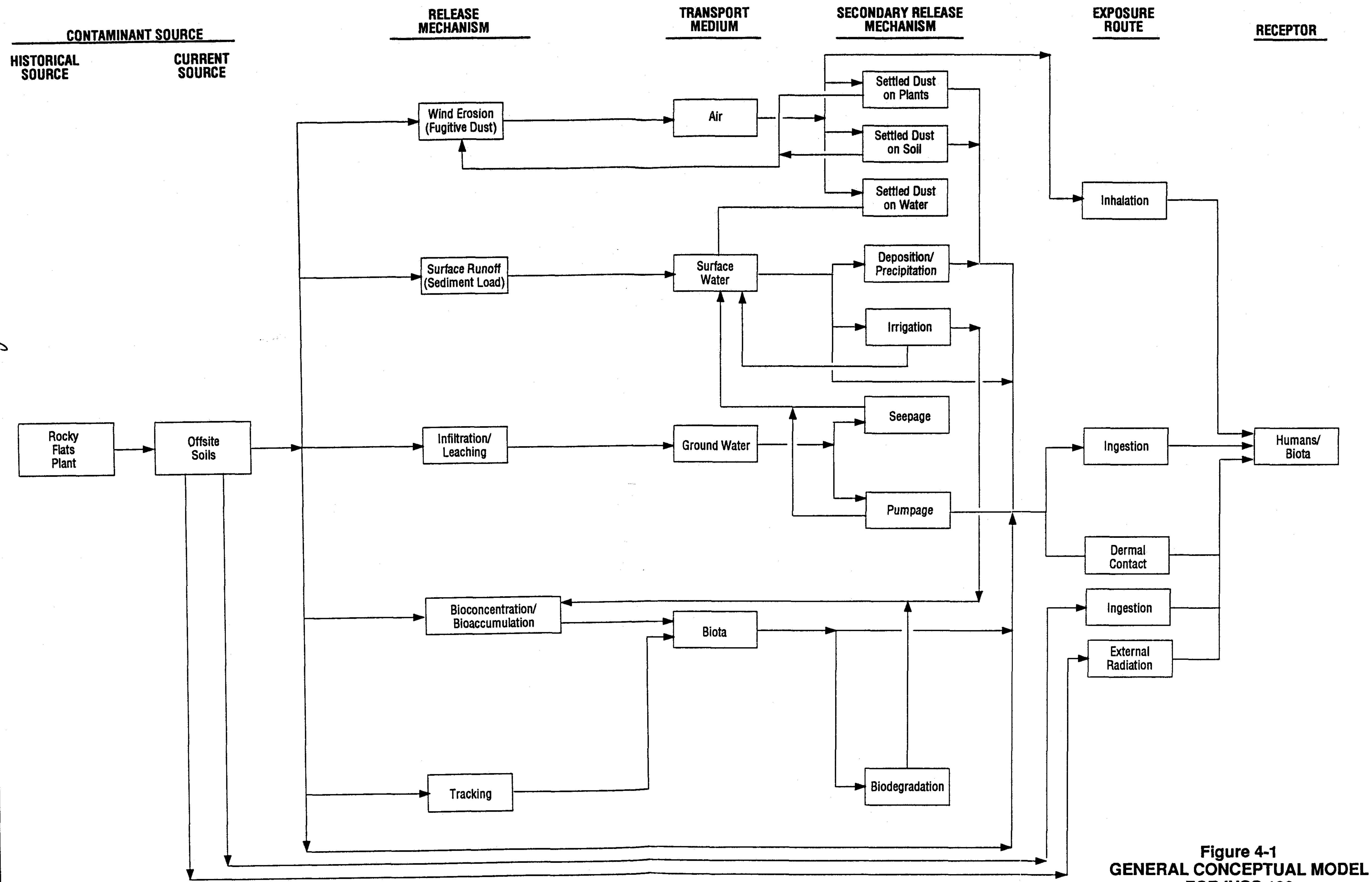

Figure 4-1
GENERAL CONCEPTUAL MODEL
FOR IHSS 199

DRAWN BY	Douville 03/09/93	CHECKED BY / APPROVED BY	P Smith 4-23-93 / J. Nitchals 4-23-93	DRAWING NUMBER	RF1059A

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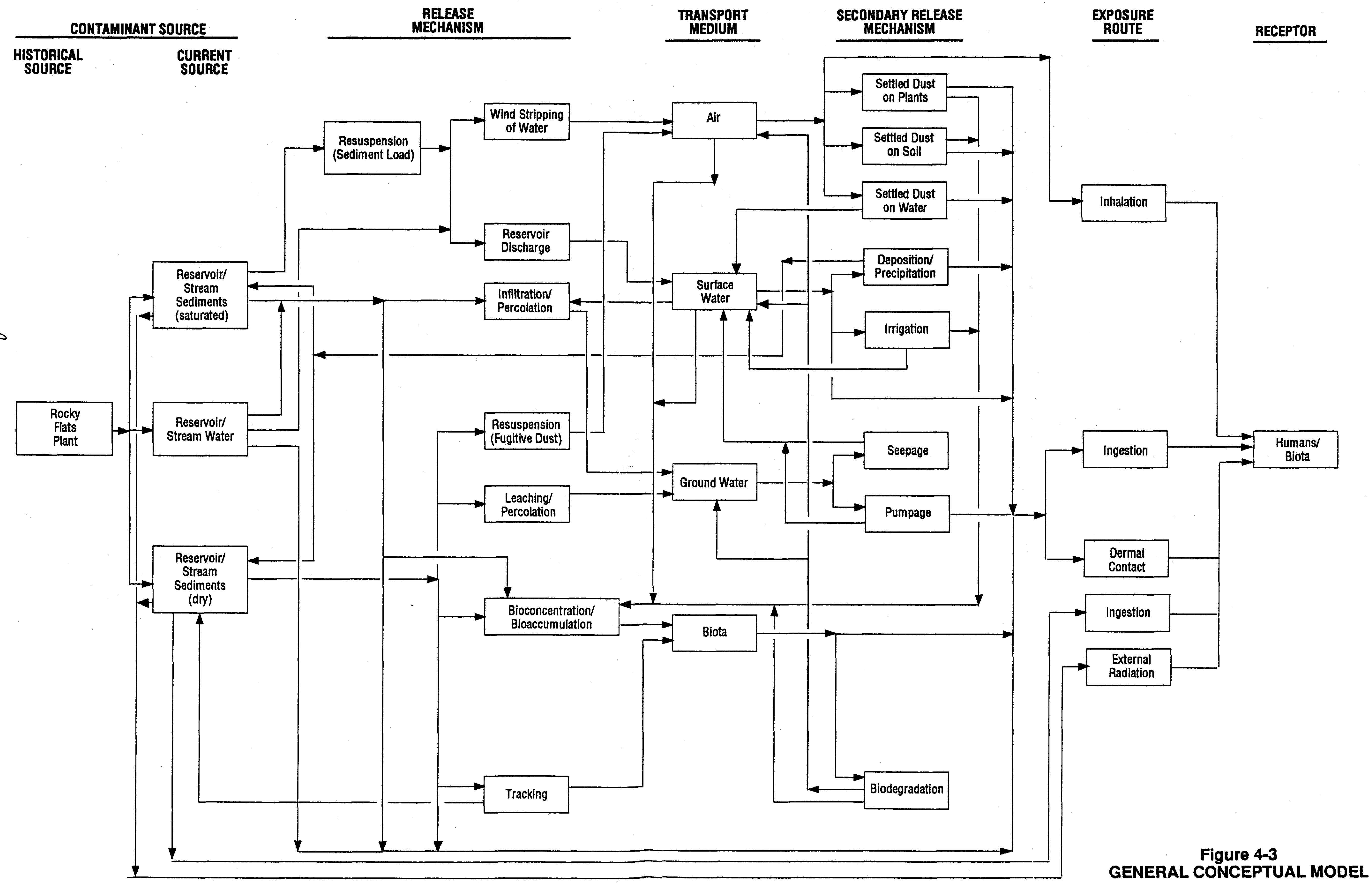

Figure 4-3
GENERAL CONCEPTUAL MODEL FOR IHSSs 200-202